Progress in Laser Risk Reduction for 1 Micron Lasers at GSFC

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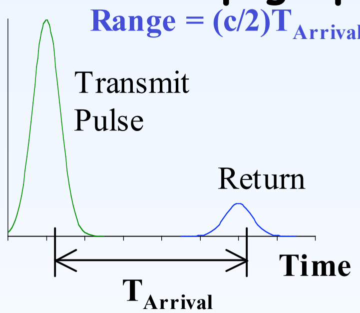
Desired Lidar Measurements

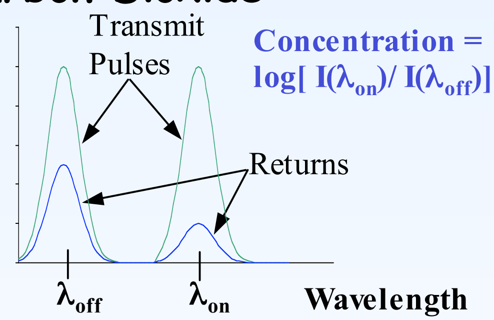
Altimetry Lidar

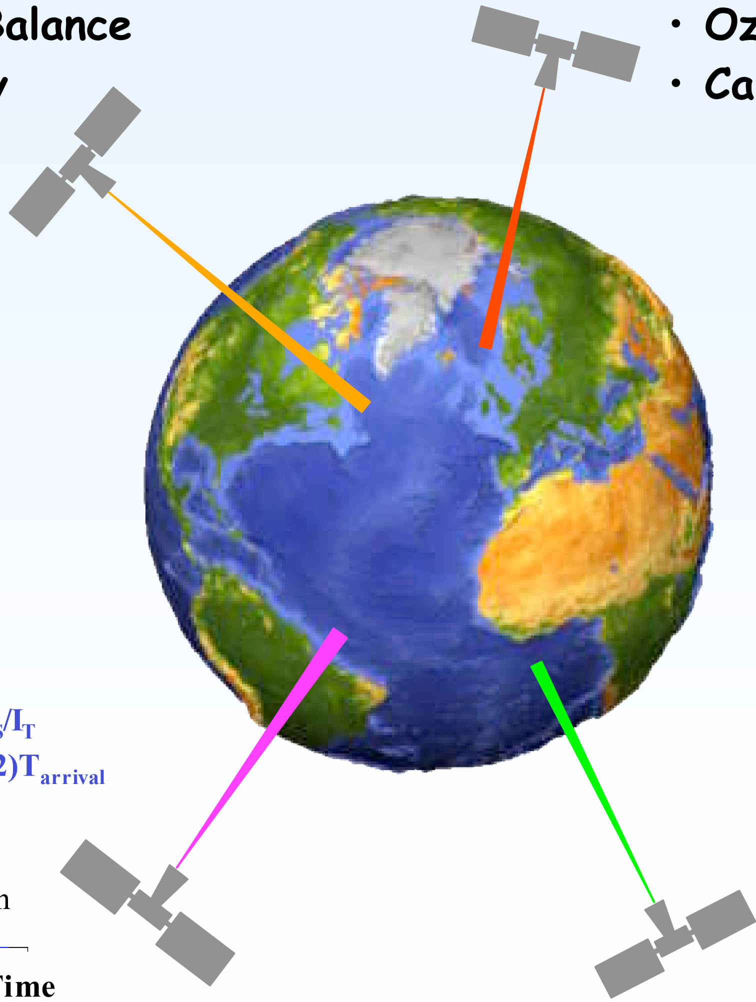
- Ice Sheet Mass Balance
- Vegetation Canopy
- Land Topography



Differential Absorption Lidar (DIAL)

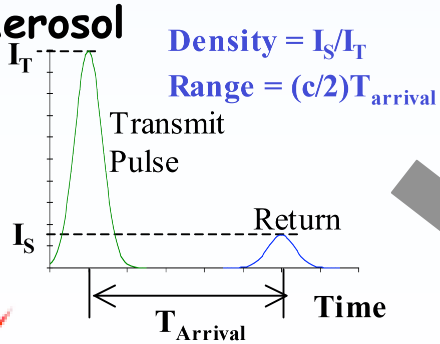
- Ozone
- Carbon Dioxide





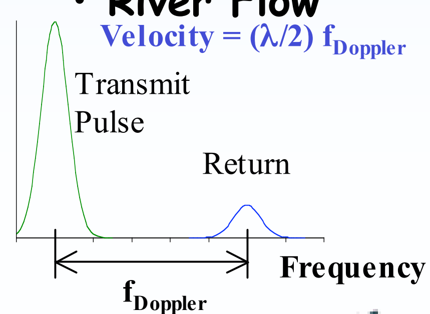
Backscatter Lidar

- Cloud
- Aerosol



Doppler Lidar

- Wind Fields
- River Flow

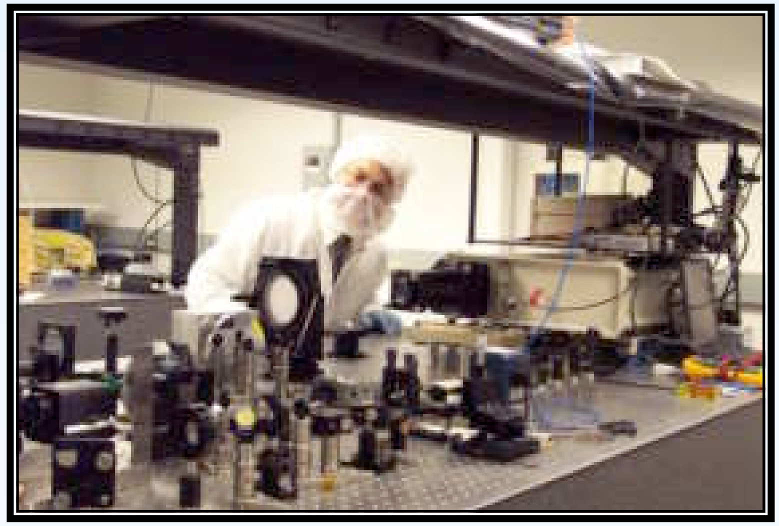


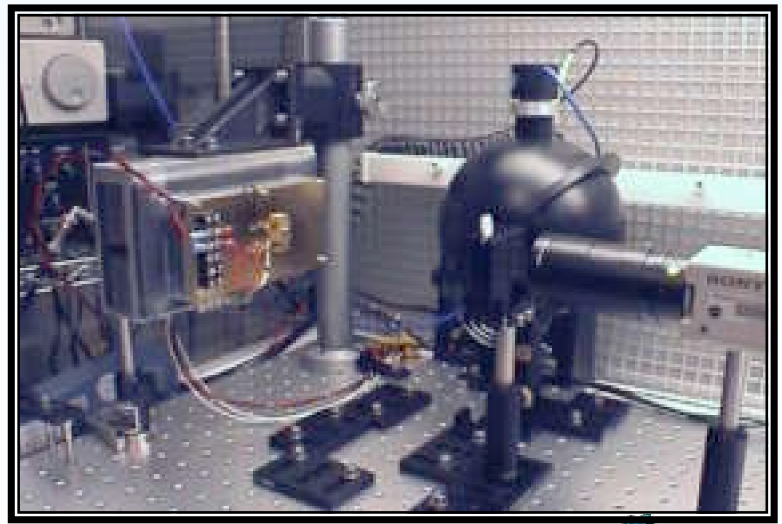
Why is space so hostile to lasers?

- Long Term Reliability
  - Impossible to service spacecraft.
  - Long development times for missions.
- Vacuum
- Vibration on launch
- Thermal Environment
- Contamination
- Reliability of components

Functional Organization of LRRP Tasks at GSFC

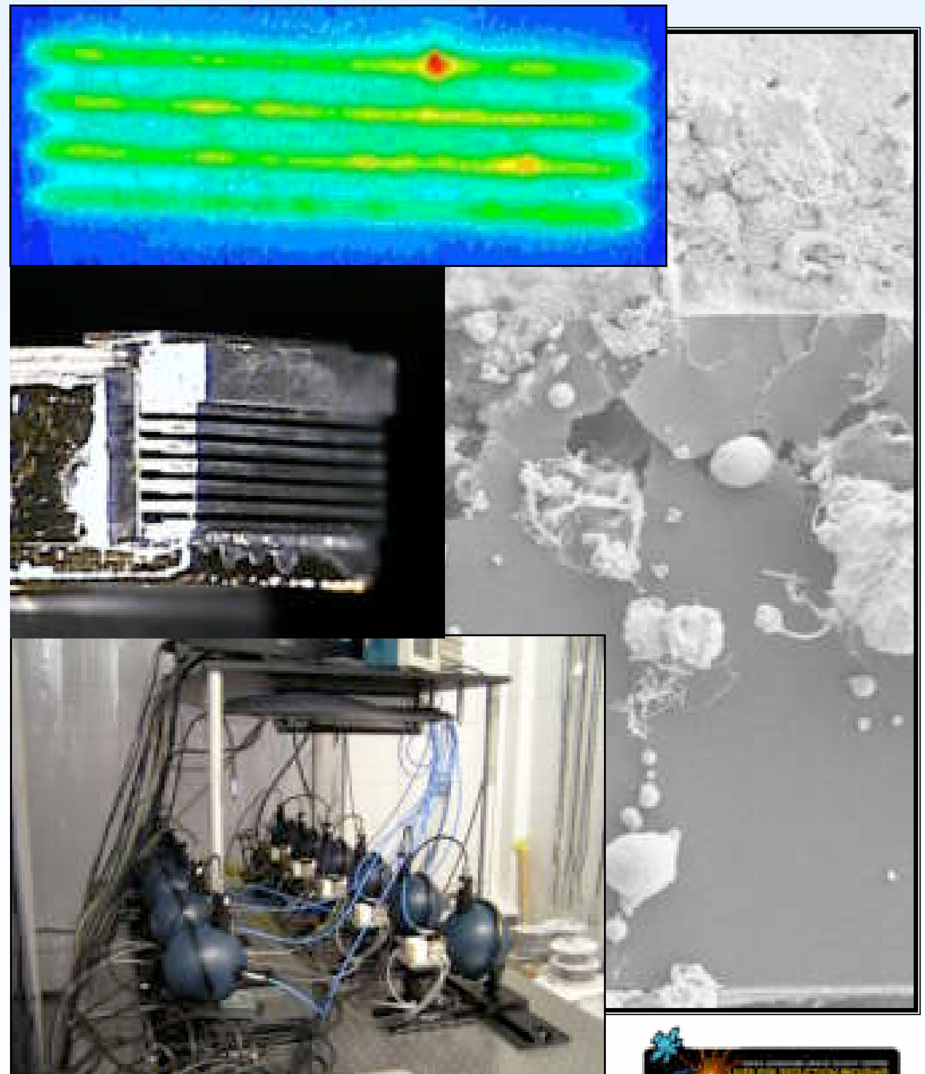
- One Micron Laser Development
  - Oscillator Architectures
  - Amplifier Architectures
  - Seeding
- Reliability Issues
  - High Power Laser Diode Arrays
  - Environmental Effects
- Space Lidar Enabling Hardware
  - Frequency Conversion & Nonlinear Materials
  - Detectors
- Knowledge Capture and Management





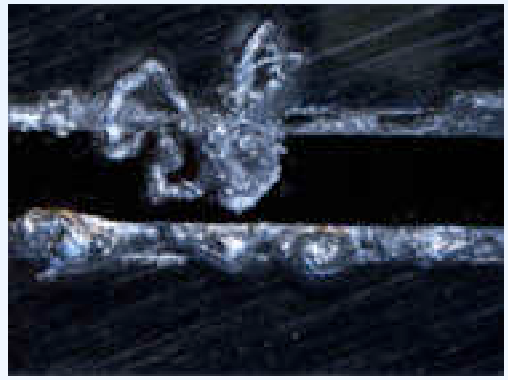
Laser Diode Reliability

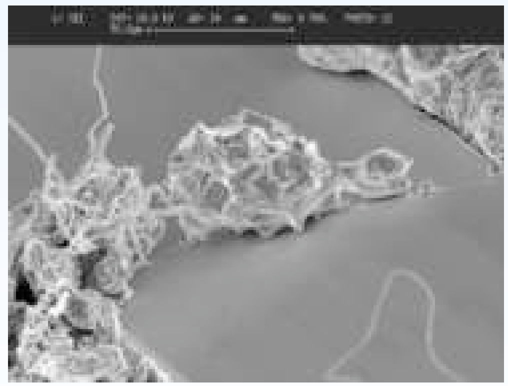
- Goals:
  - Quantify effect of operational and environmental parameters on Laser Diode Array (LDA) performance.
  - Develop procedures for purchasing, handling, storage and operation.
  - Develop prediction/screening capability.
  - Enable improved reliability and performance of future laser missions.

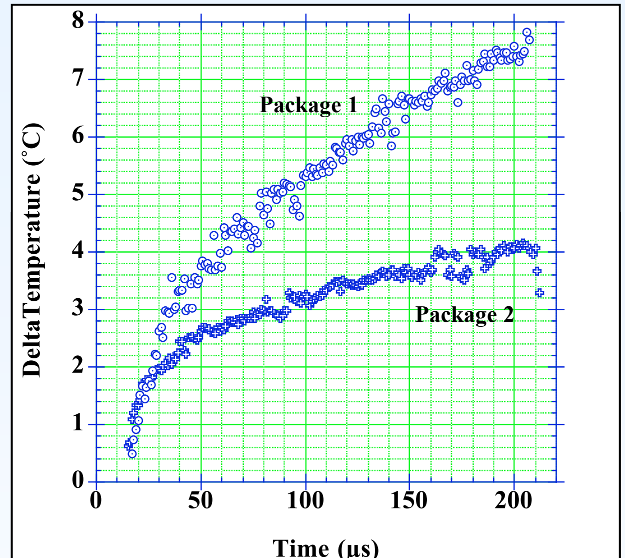


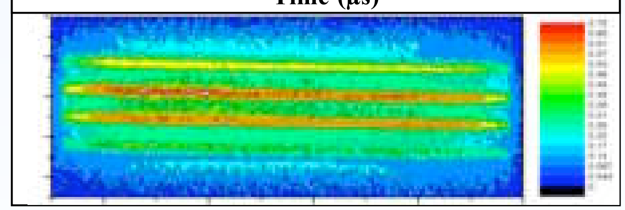
LDA Diagnostic Capabilities

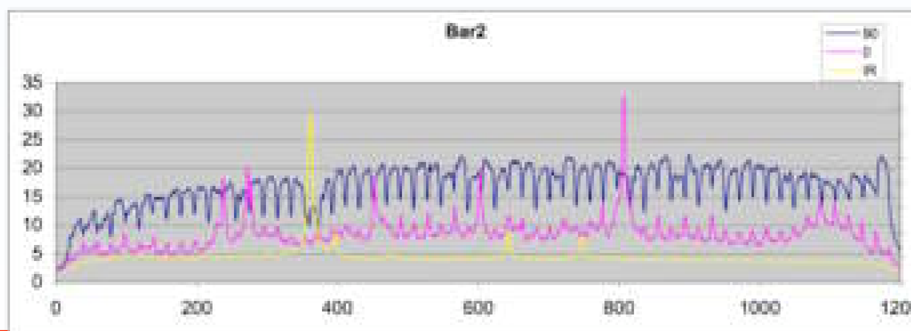
- Optical power measurement
  - Average
  - Spatially resolved
  - Polarization resolved
  - Temporally resolved
- Electrical parameters
  - Voltage
  - Current
  - Efficiency
- Thermal Profiling
  - Temporally, spatially resolved surface imaging
  - Thermal modeling
- Spectral Measurement
  - Spatially, temporally Averaged
  - Time-resolved spectroscopy
  - Spatially resolved spectroscopy
- Facet Microscopy
  - Near, dark field
  - Extended focal imaging
  - Side view
  - SEM





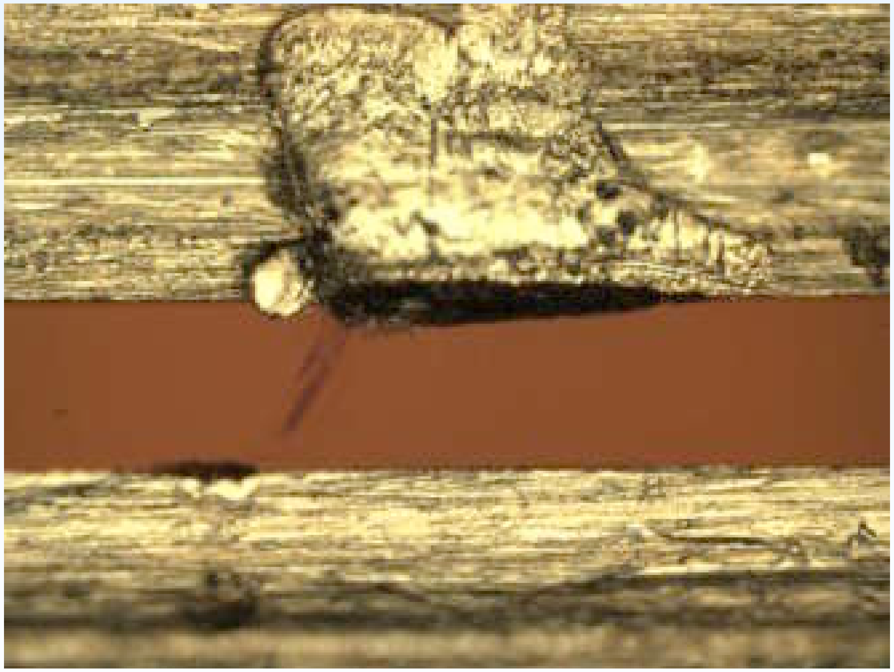






20x Bright Field Facet Image of G18 Array

S/N:22498



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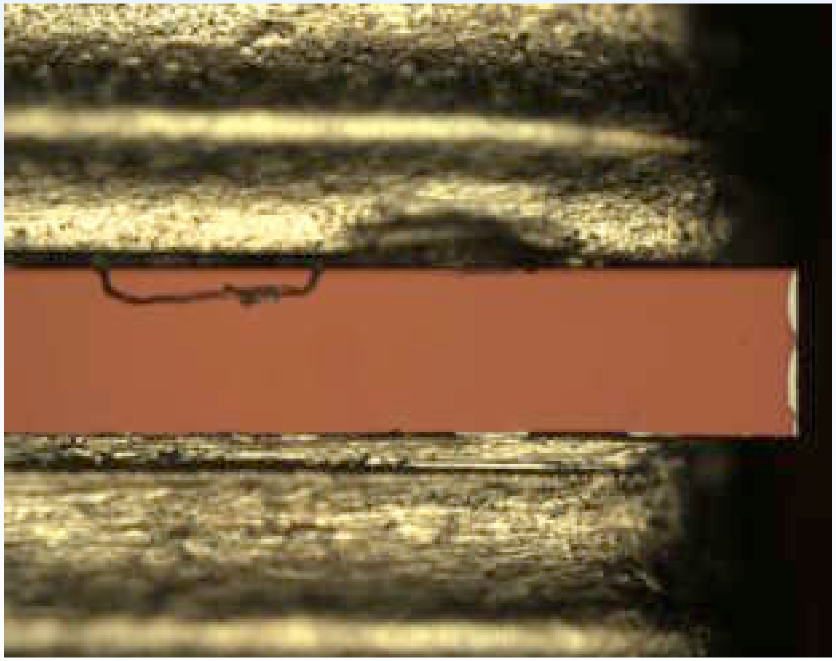
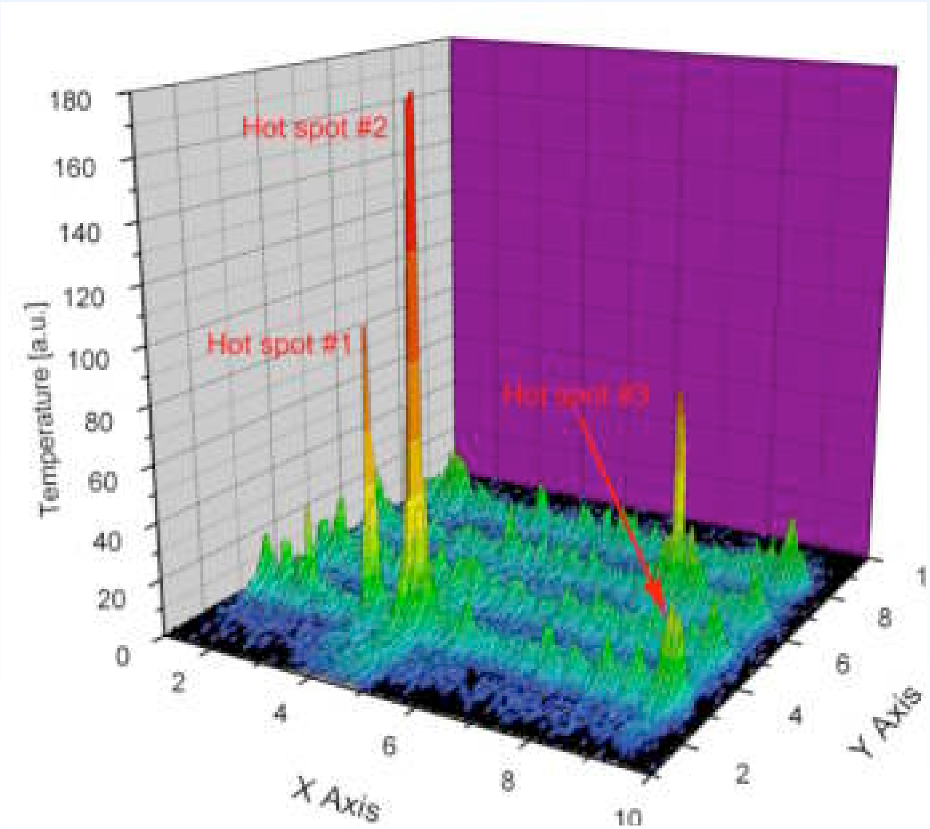
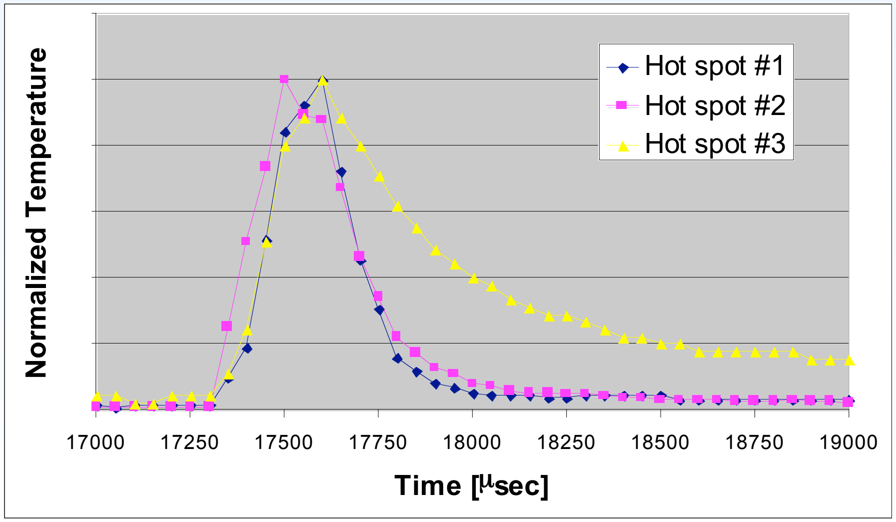


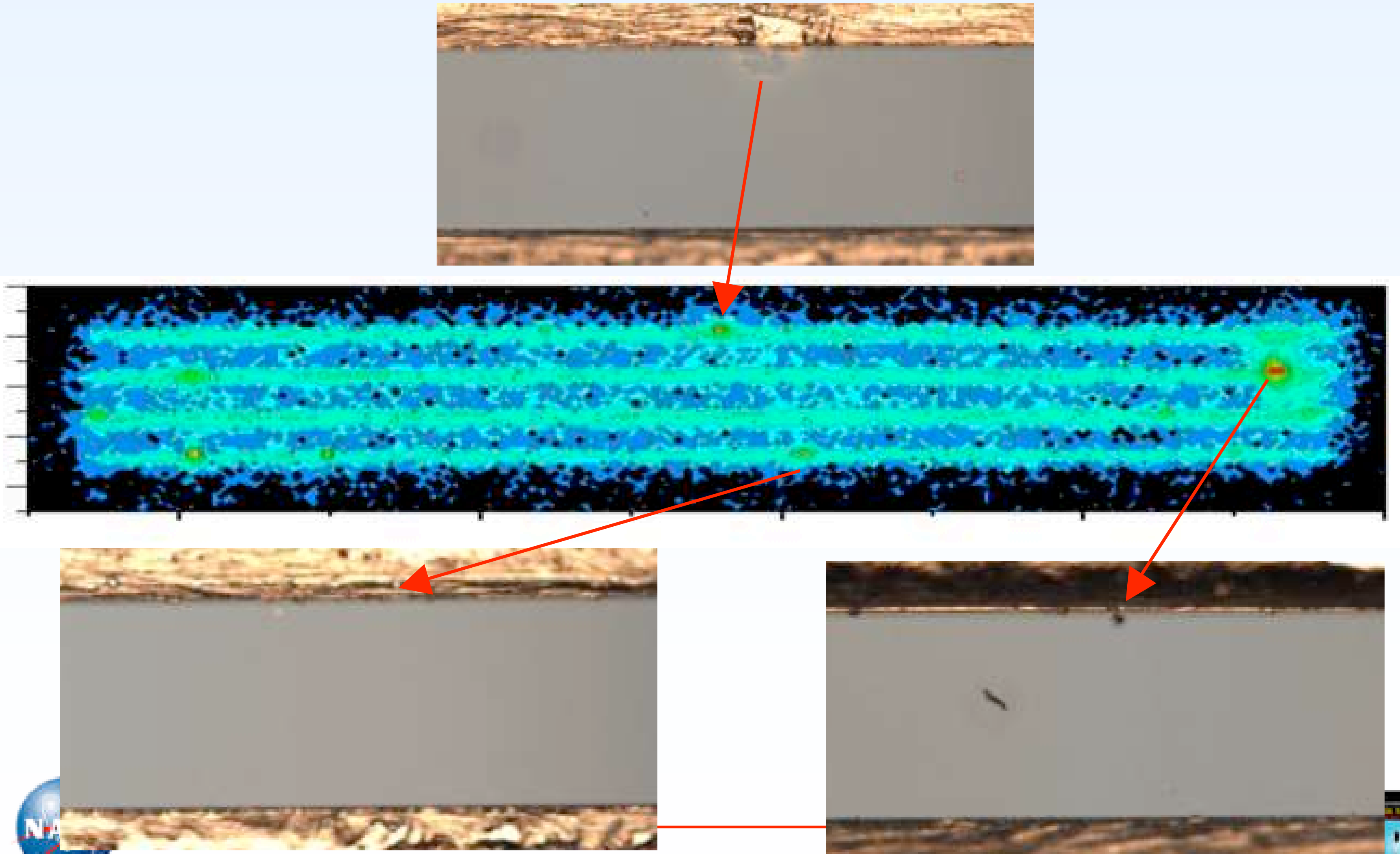
LDA Characterization

IR Inspection - Temporally Resolved IR Measurements

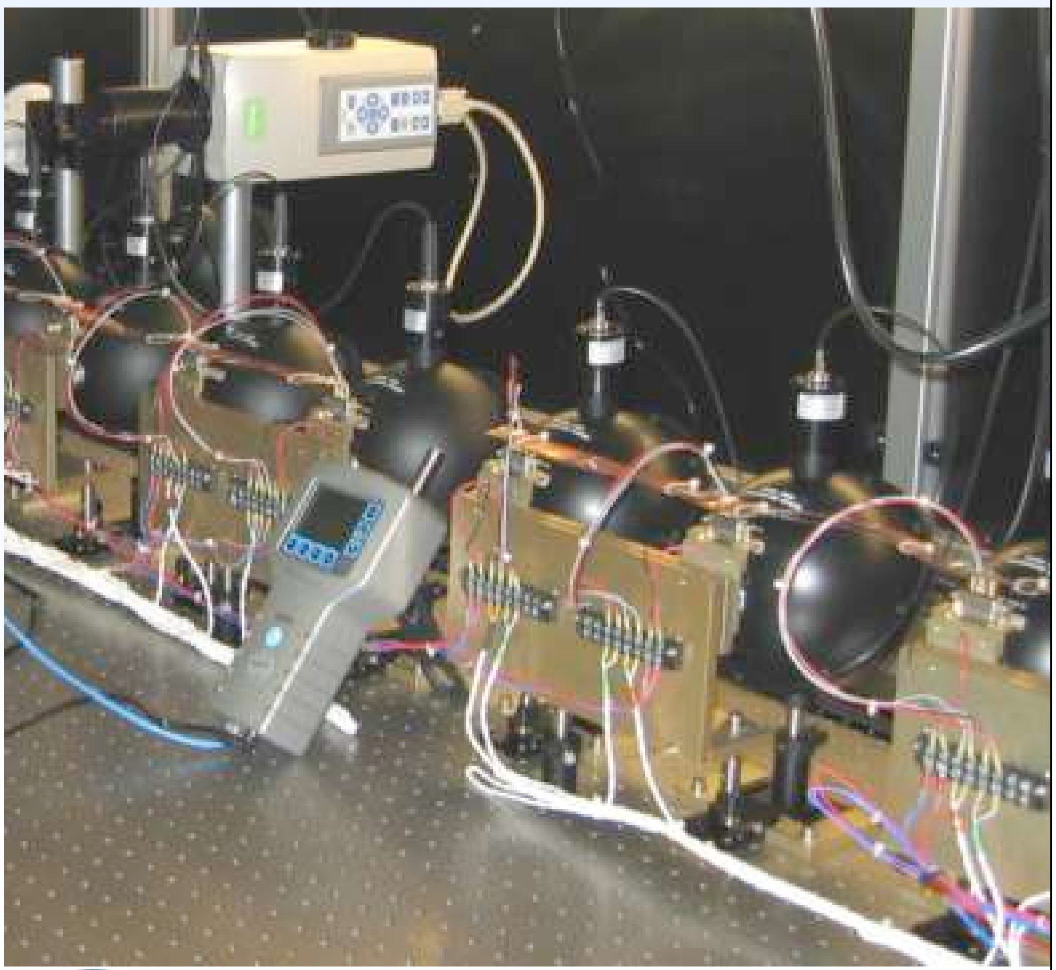


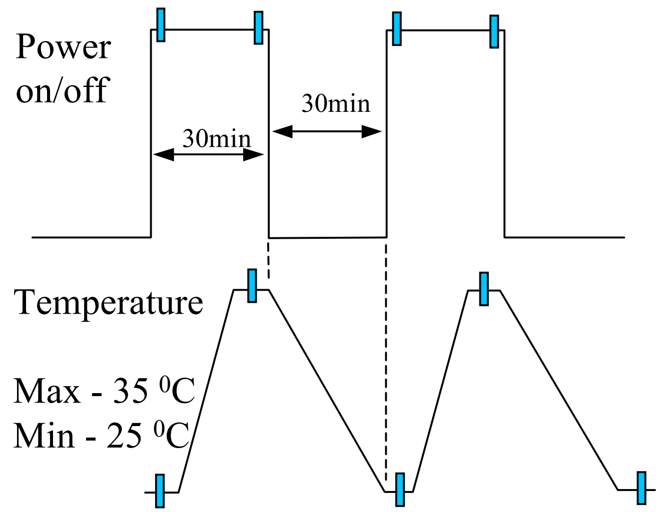


Correlation Between IR and Microscope Images



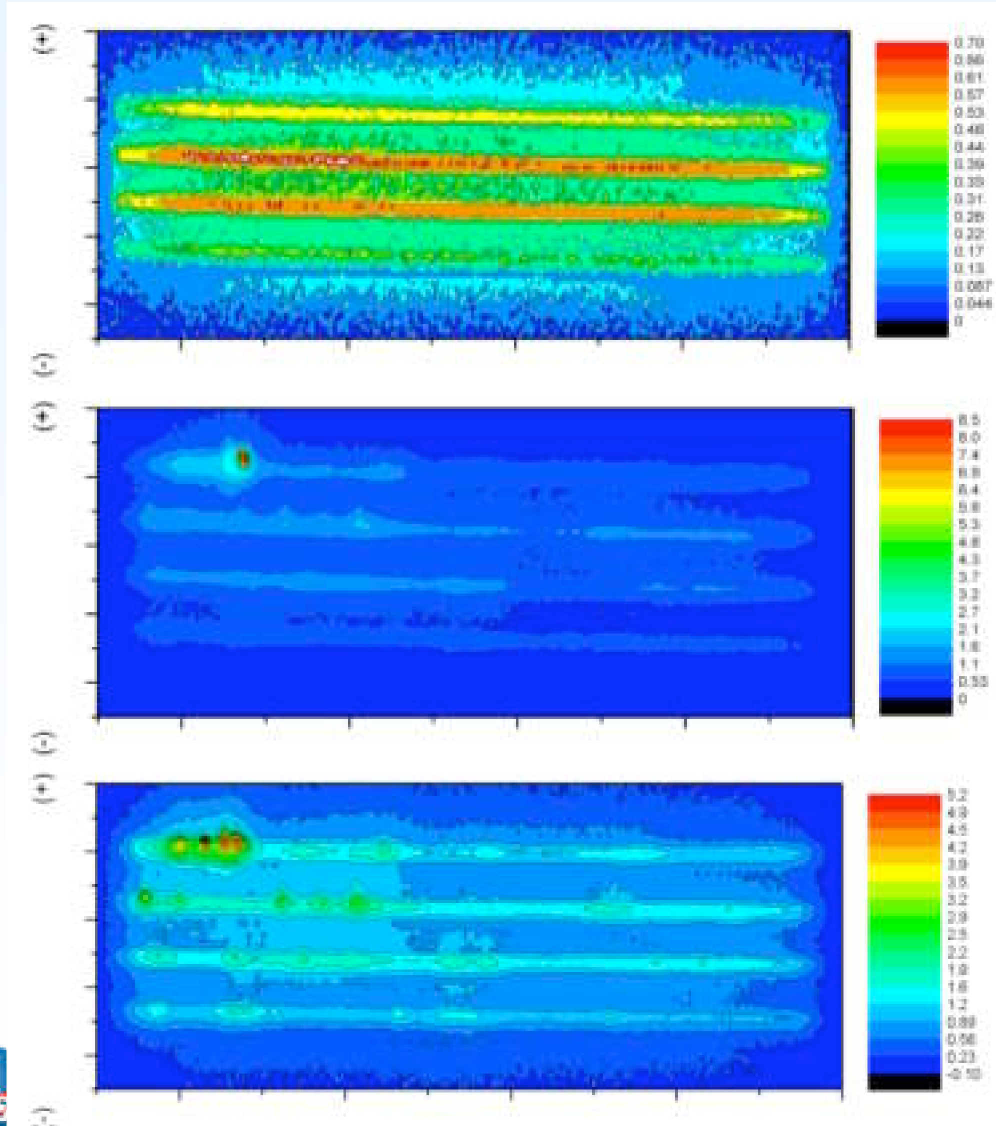
Power / Temperature Cycling





	Constant Temperature	Temperature Cycled
Constant Power	2 G2's 2 G4's	2 G4's
Power Cycled	2 G4's	2 G2's 2 G4's

LDA IR Images of G1740 from TCP Test

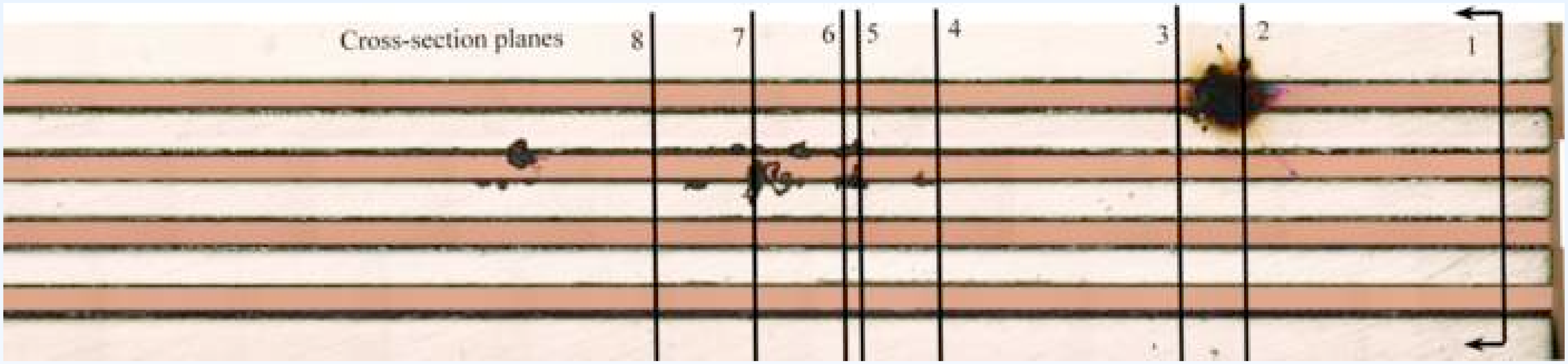


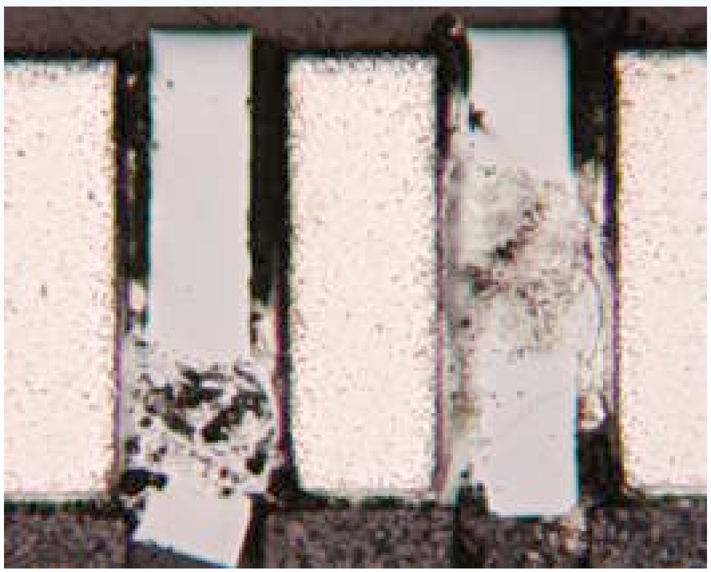
7-9-2003
Initial

12-11-2003
after 110.000.000 pulses

6-10-2004
after 200.000.000 pulses

DPA 1776: Cross-section Analysis

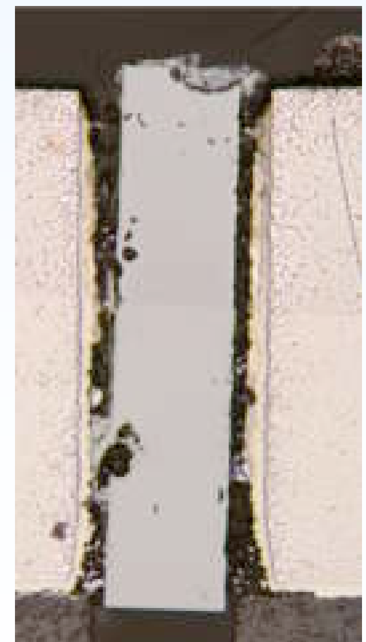




D2&3 L6

D2 L5

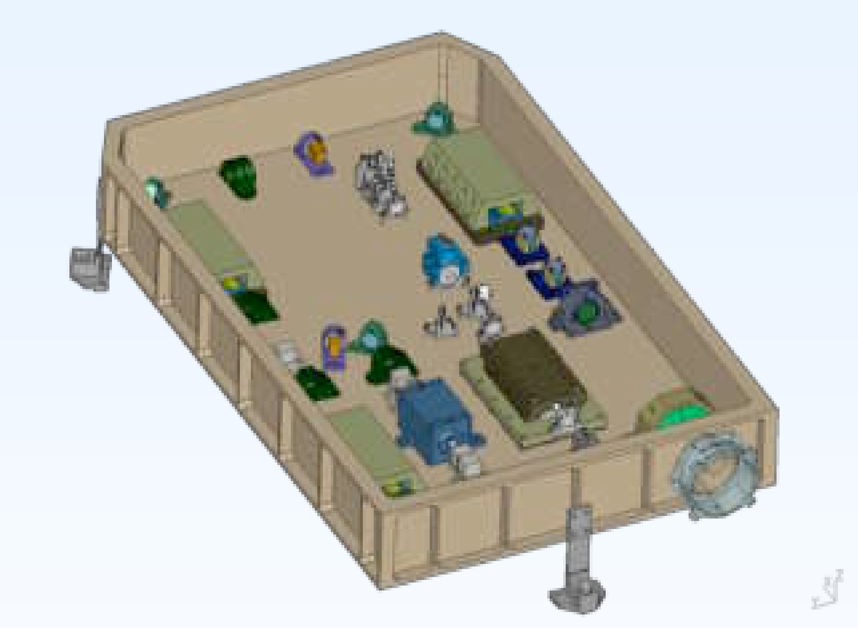
D2 L3

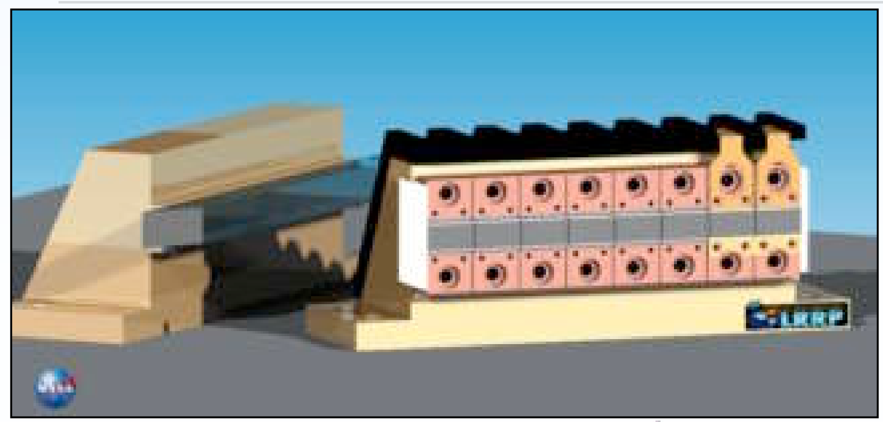


D1 L2

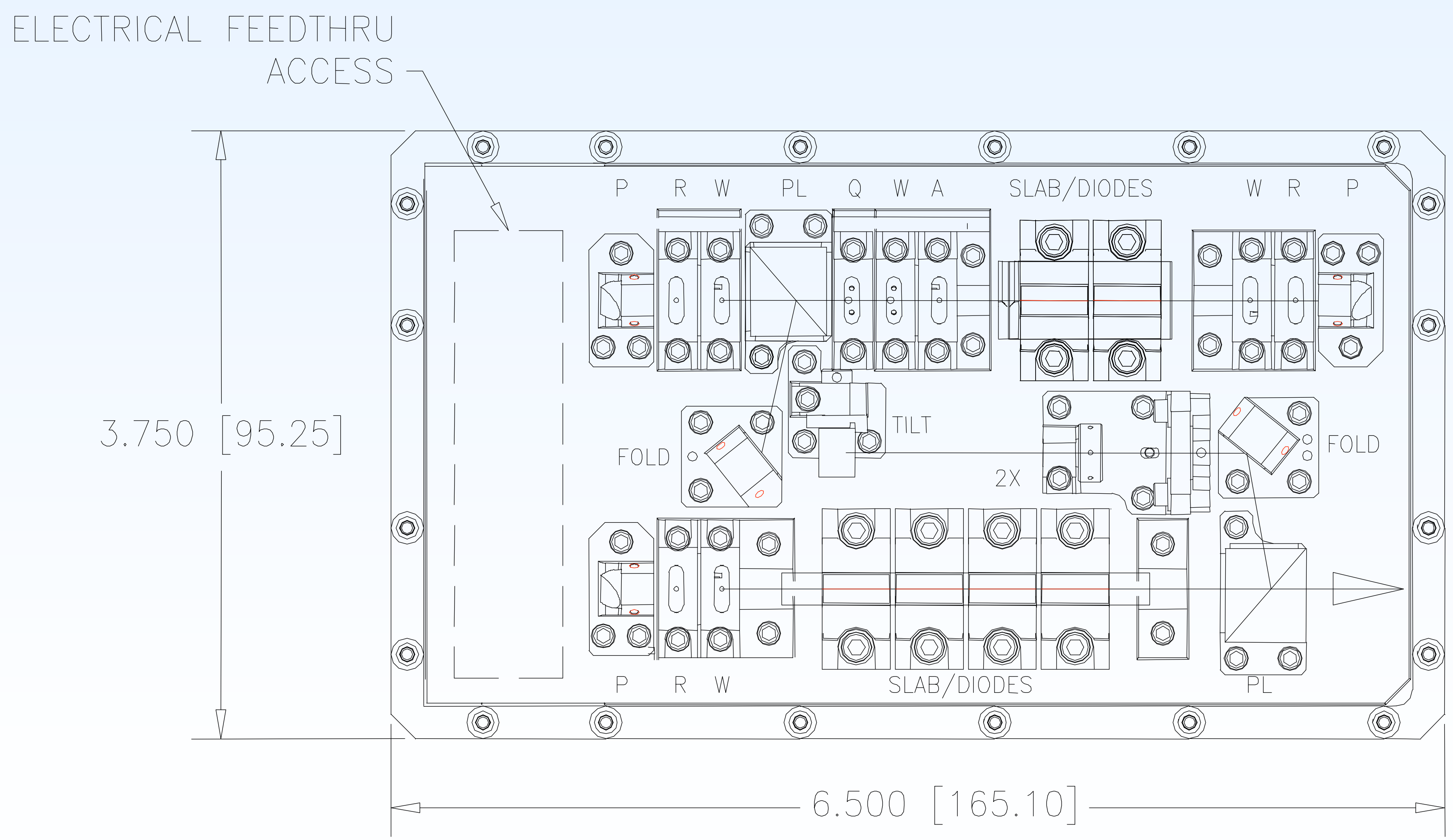
Laser Development: 1 micron laser

- Goal: Develop and demonstrate technologies leading to a diode-pumped 1-micron, 1Joule 100 Hz laser for space-based operations
- Design Features:
  - Several oscillator designs
  - Three optical amplifier stages.
  - Frequency stabilized 1064 nm laser seeder unit.
  - Robust opto-mechanical design.
  - Status of effort:
  - Oscillator assembly in process.
  - Amplifier in assembly
  - First order packaging design complete
  - Laser seeder design complete, packaging effort underway.





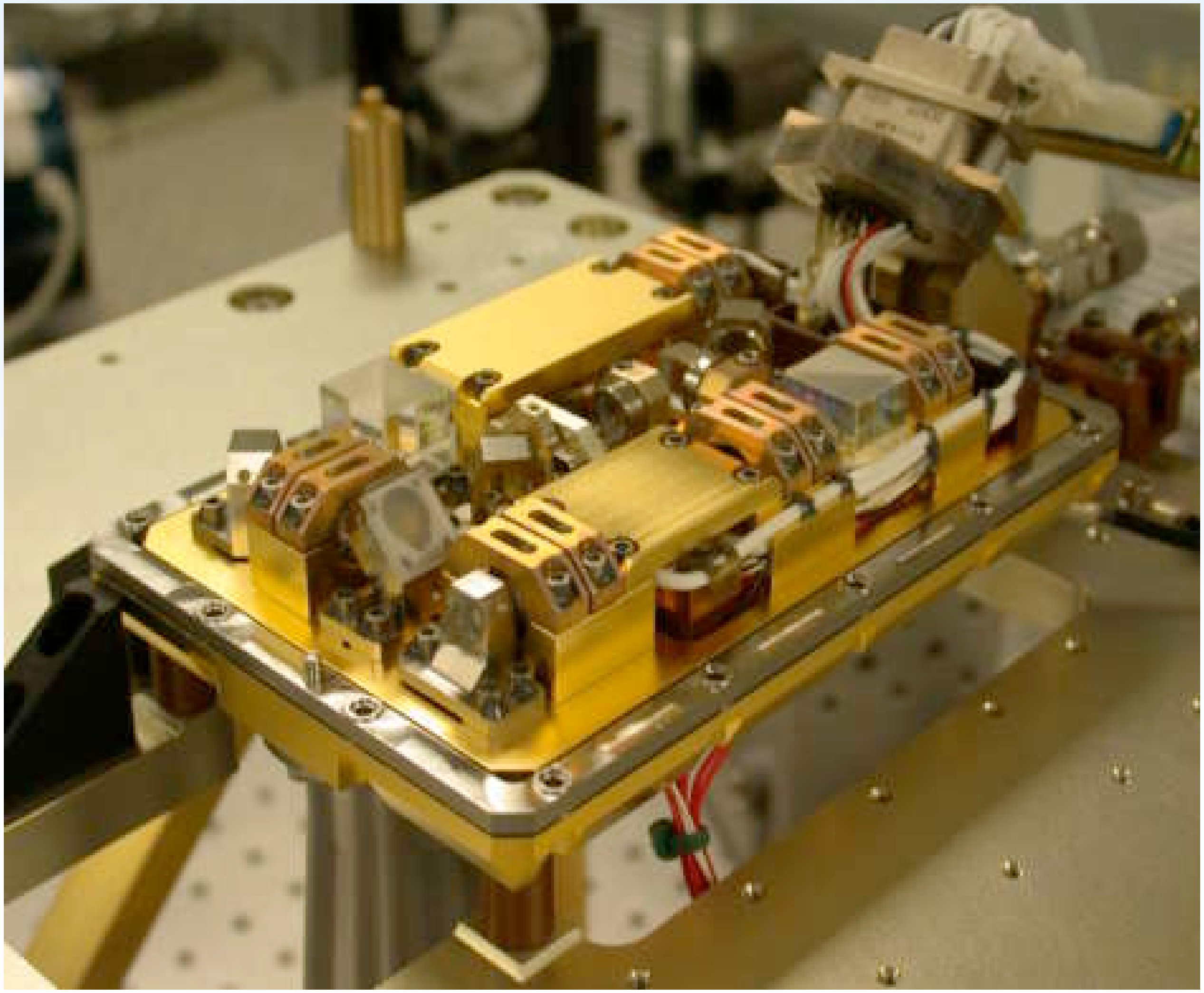
Oscillator Development



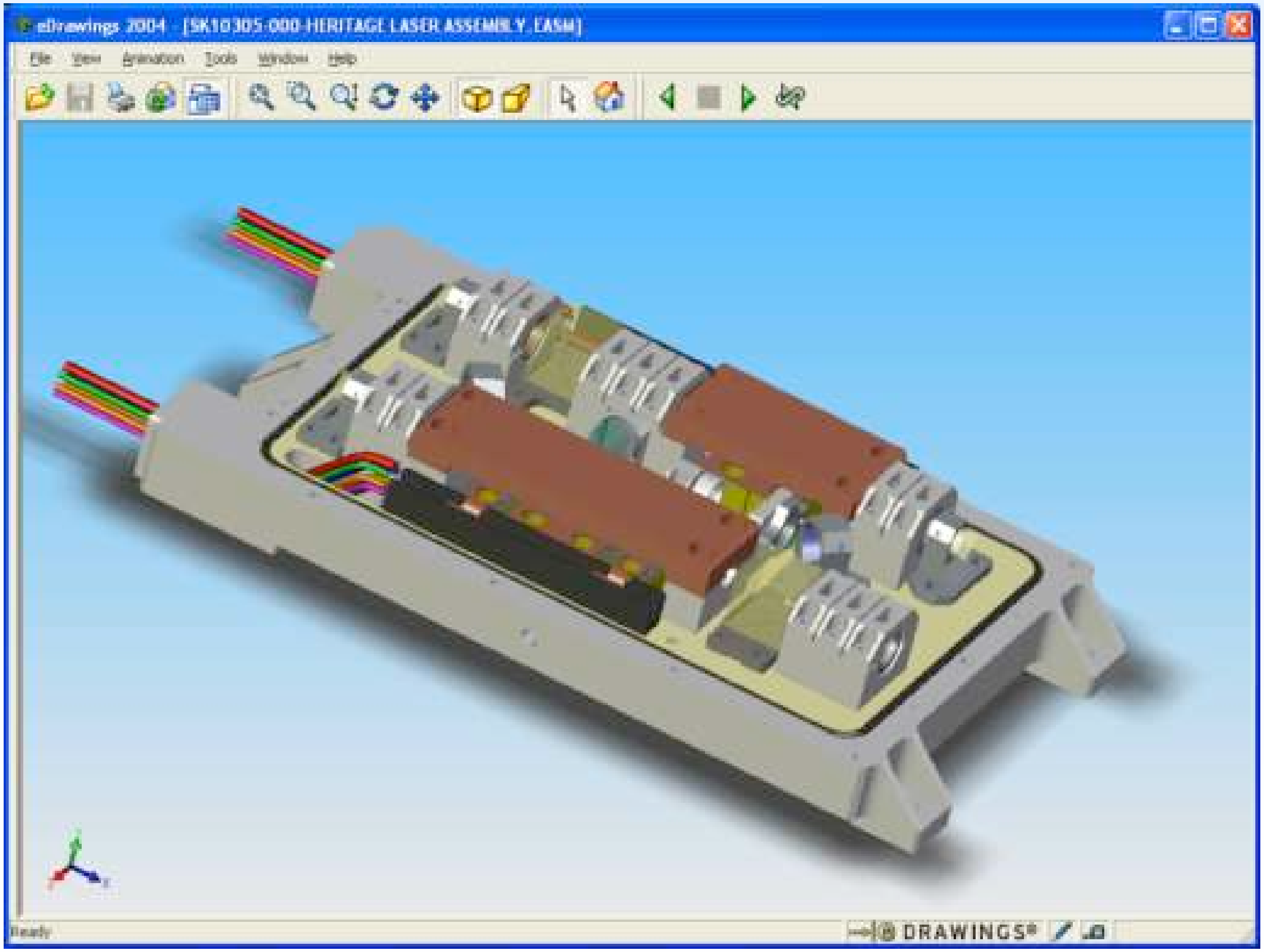
'Heritage' Task Objectives

- A MLA-like low power (15mJ, 40-100 Hz) laser for vacuum life test. PLUS
  - Increase the laser pulse repetition rate (from 40 Hz to 100 Hz)
  - Improved electronics design (automatically sense of bars open).
  - Improved optical design (spatial mode and pointing stability).
  - Improved laser lifetime (derating of laser diodes by 40%)
  - Following the flight build protocols.
- Will be used for contamination test for different adhesive and material under controlled fashion.
- The knowledge gained from this task will greatly reduce the risk for flight projects with the similar laser design/requirements

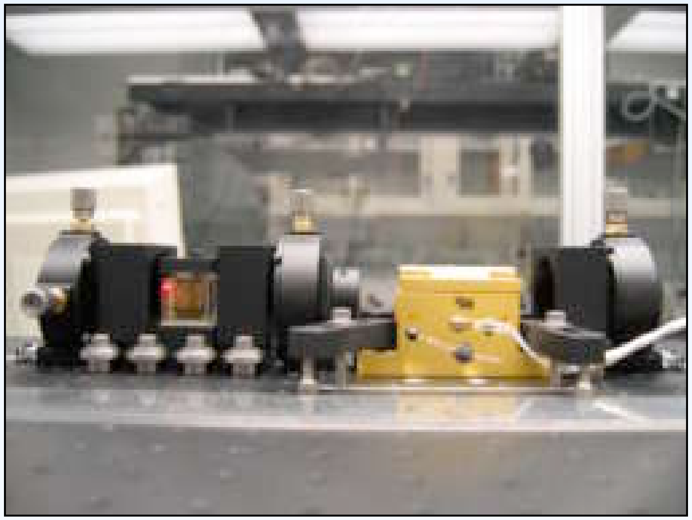
MLA Laser

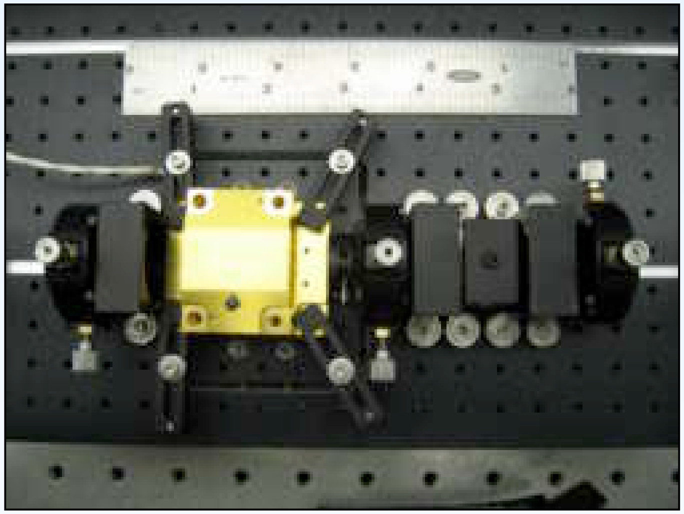


Heritage Laser Packaging



Heritage Laser Breadboad Development

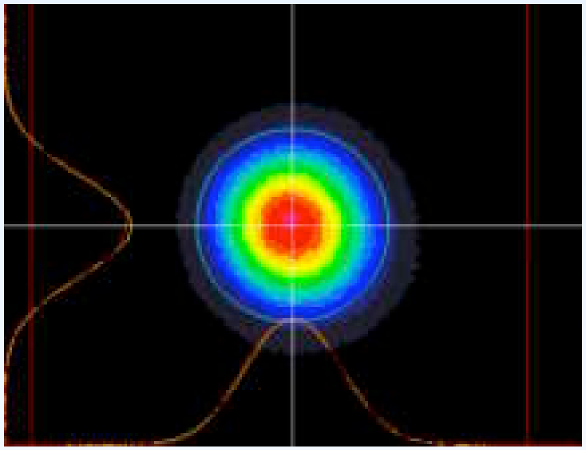




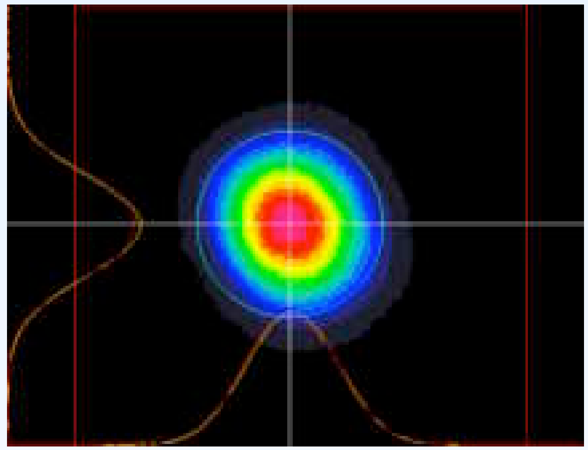
- Developed a breadboard that could be easily built and modified
- Recent results:
  - highly stable TEMoo operation with a 2.2 mm thick slab
  - high repetition rates (~200 Hz) do not appear to be a problem
  - single longitudinal mode operation favored
- Testing with other slab thicknesses (1.2 mm, 1.4 mm, and 1.7 mm) is planned.

Breadboard Oscillator Performance

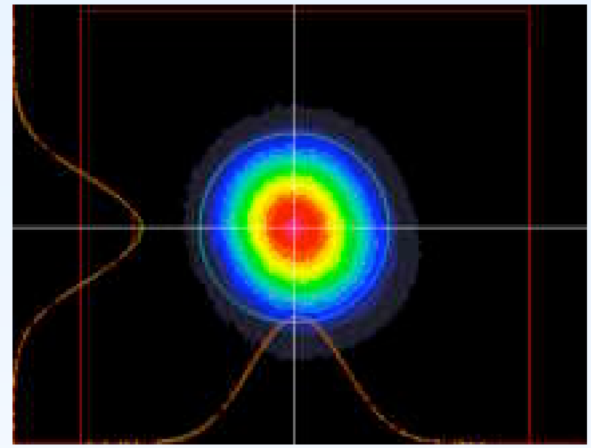
Diode pump current: 75A, Laser output: 2.6mJ



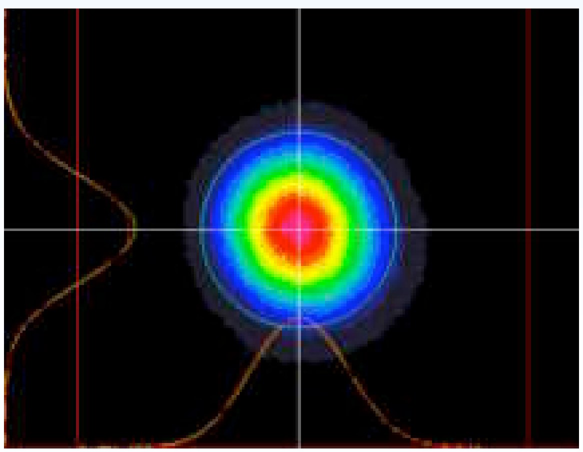
20 Hz



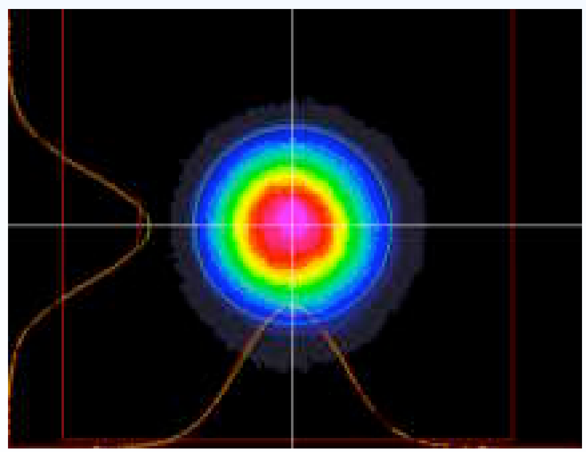
40 Hz



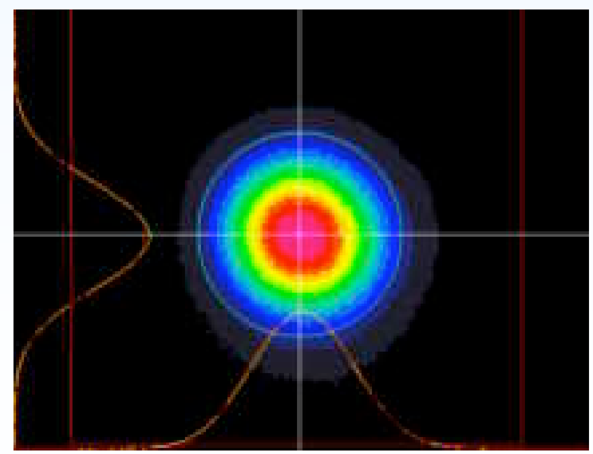
80 Hz



120 Hz

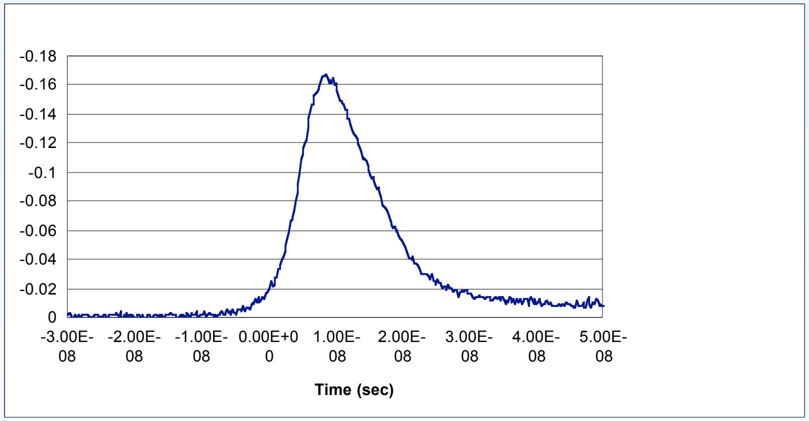


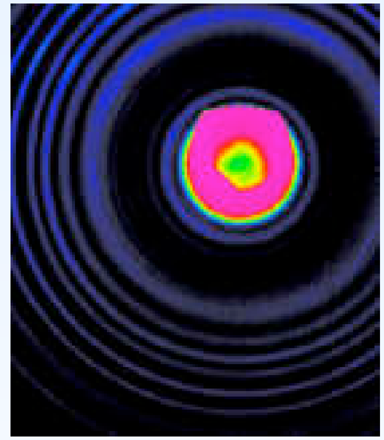
160 Hz



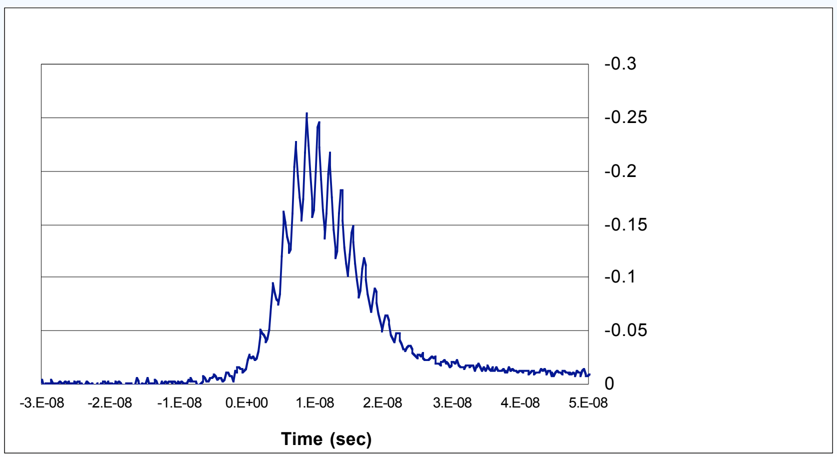
200 Hz

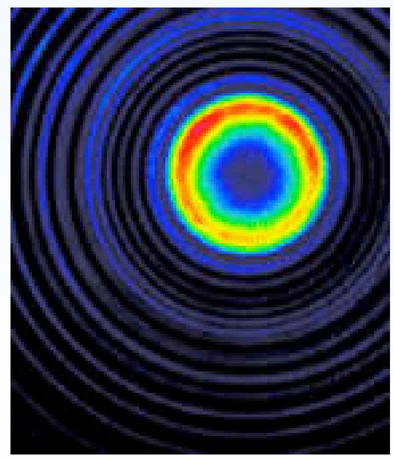
Breadboard Longitudinal Modes





Single Mode





Dual Mode

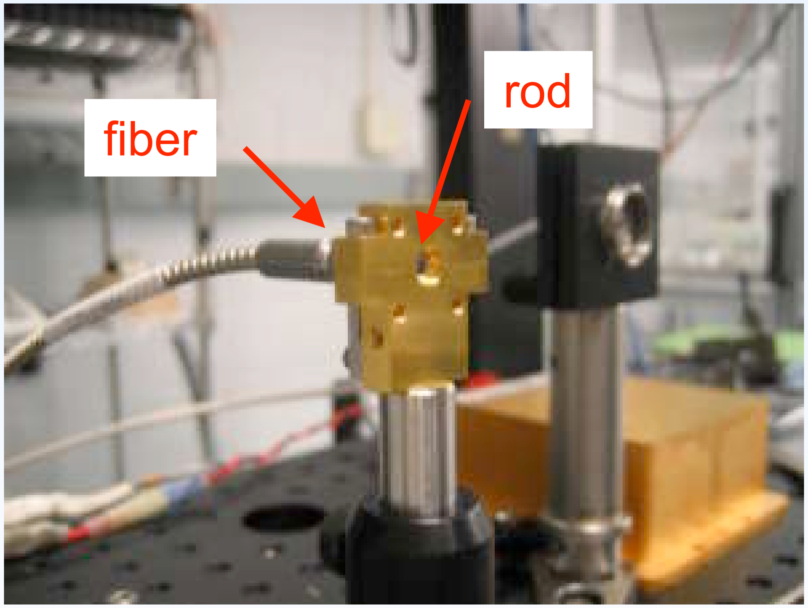
Temporal Pulse Shape

Fabry-Perot Ring Pattern

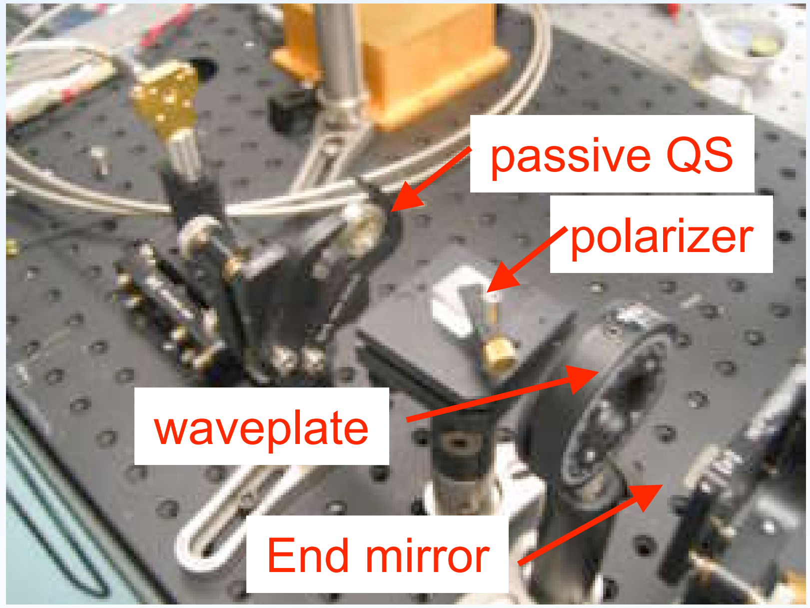
High-Pulse-Rate Laser

- Goal: Develop a reliable, high-pulse-rate (1-10 kHz) laser with pulse energy greater than 0.5 mJ for altimetry applications.
- Approach: End-pumped lasers using the new CW fiber-coupled diode arrays now available. These devices typically provide 10 to 40 watts of CW pump light from a 400-800 micron aperture (0.2 numerical aperture).
- Issues to be addressed:
  - laser energetics and general feasibility of approach
  - pump coupling and resonator design trades
  - limitations due to thermal loading
  - active versus passive Q-switching
  - monolithic versus component design

High Rep Rate Setup with Passive Q-switch

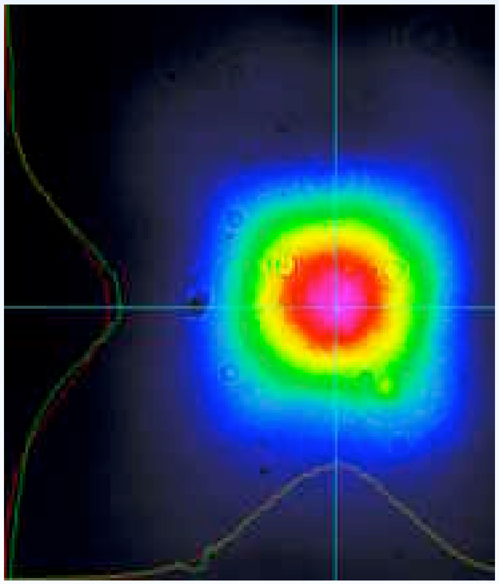


Pump Head

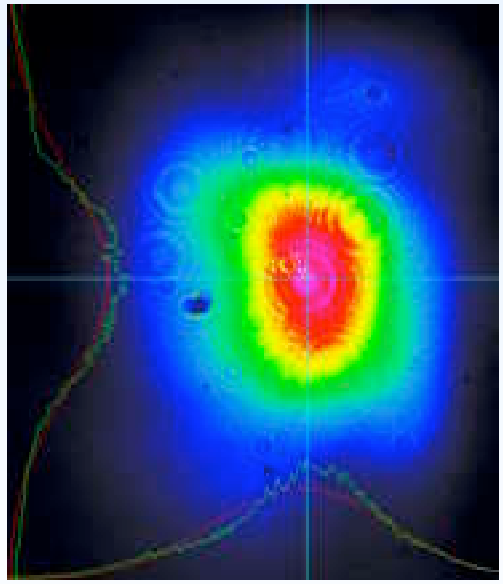


Laser Cavity

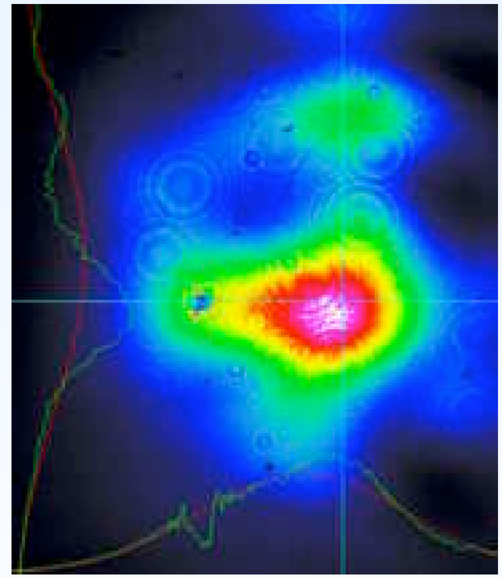
High Rep Rate Performance with Acousto-Optic Q-switch and CW Pumping



~440 µJ, ~ 9 ns
(diode: 19.0A CW)



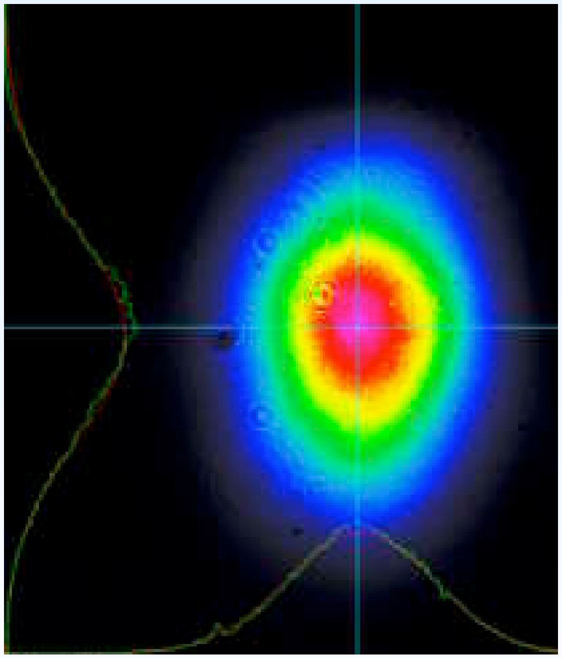
~410 µJ, ~ 9 ns
(diode: 20.0A CW)

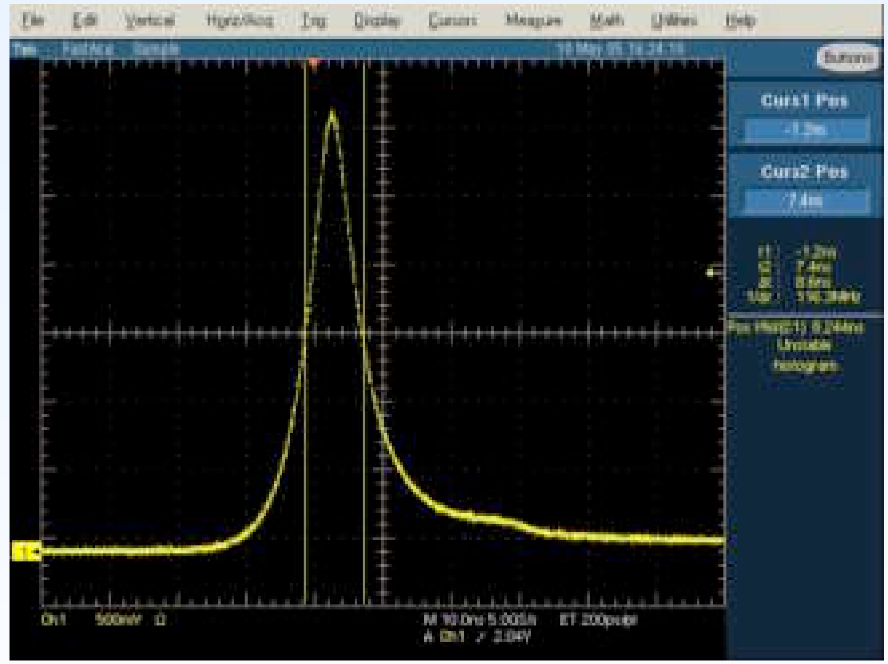


~500 µJ, ~ 8 ns
(diode: 21.3A CW)

- 15 cm cavity, flat/flat
- R = 80% output coupler
- Beam profiles captured in "transition region", not far field

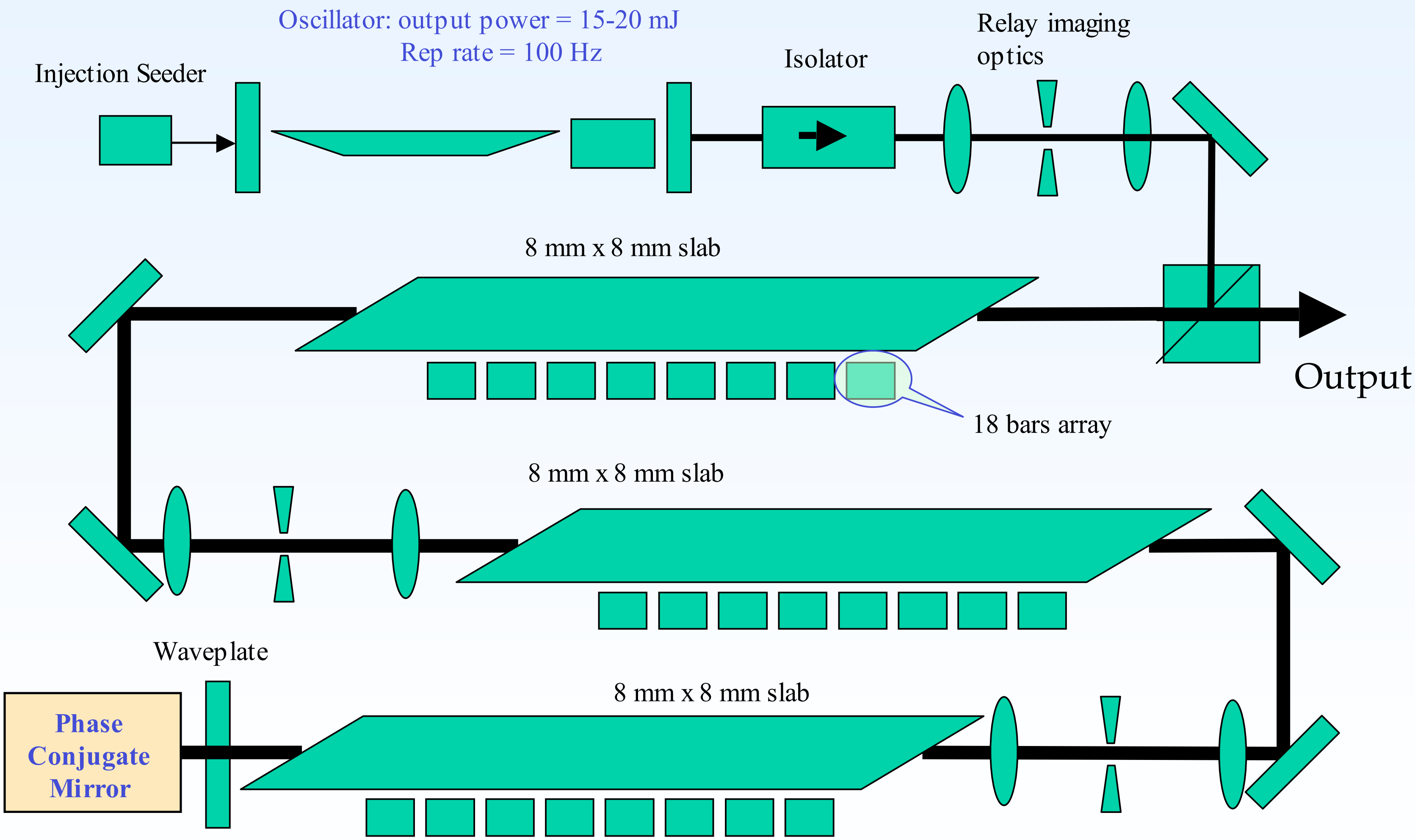
High Rep Rate Results with AO Q-switch and QCW Pumping



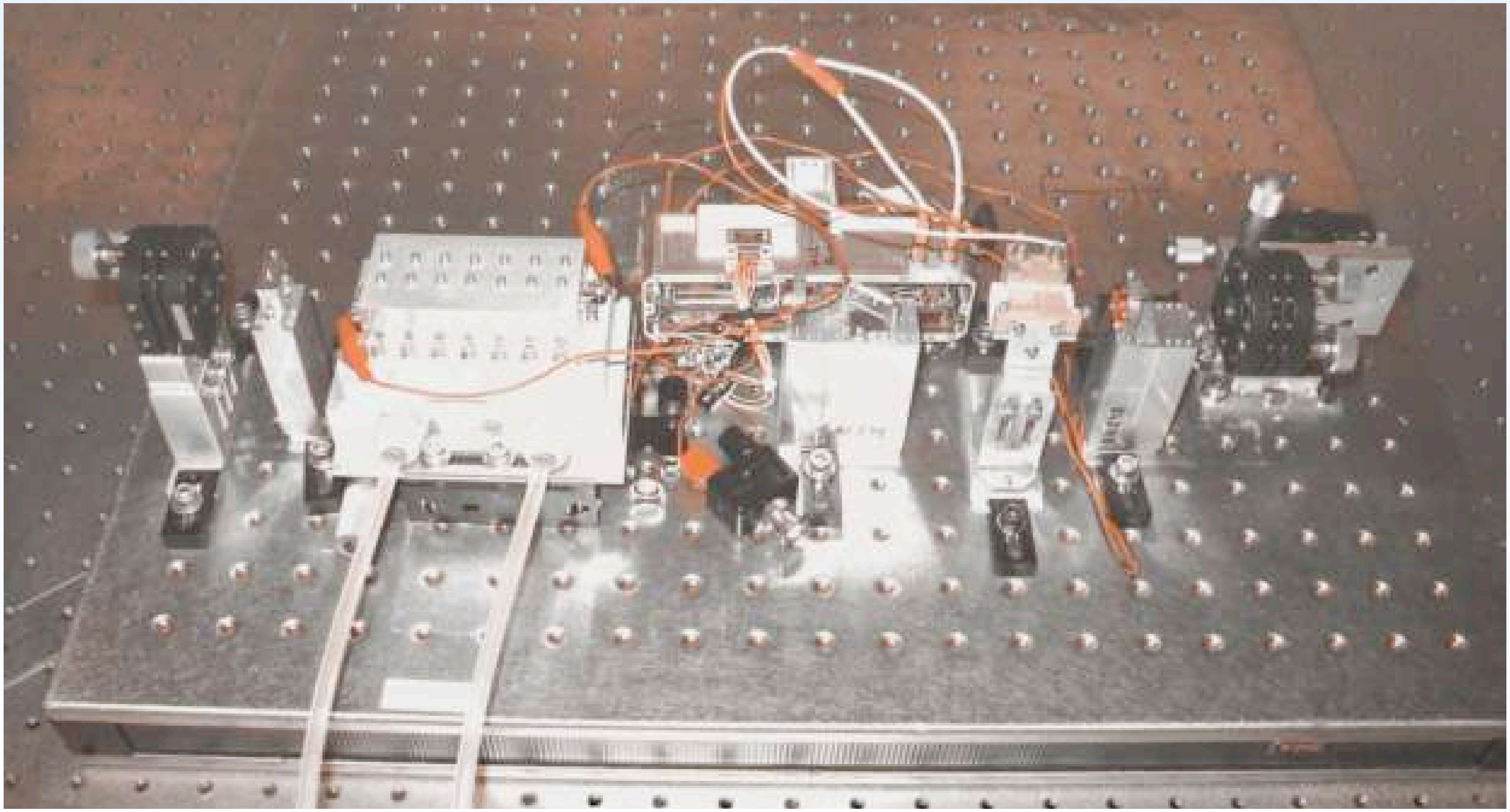


- 200 μs pump pulse width, 1 kHz
- Pumping conditions: 26.5 A, 20% duty cycle, ~18 watts peak optical
- Output energy ~ 0.5 mJ, pulse width = 7.9 nsec, ~14% optical-to-optical efficiency

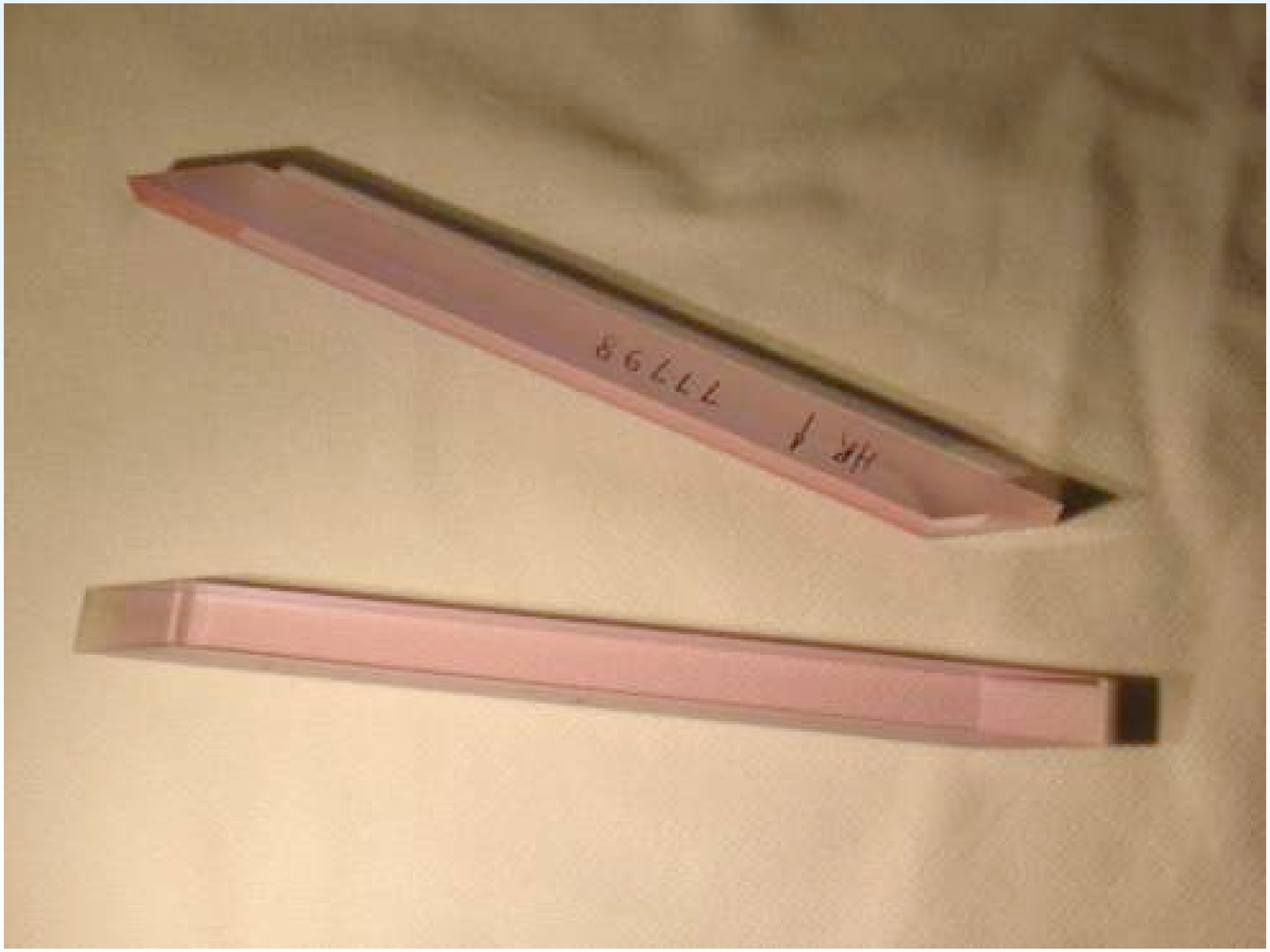
Amplifier Architecture



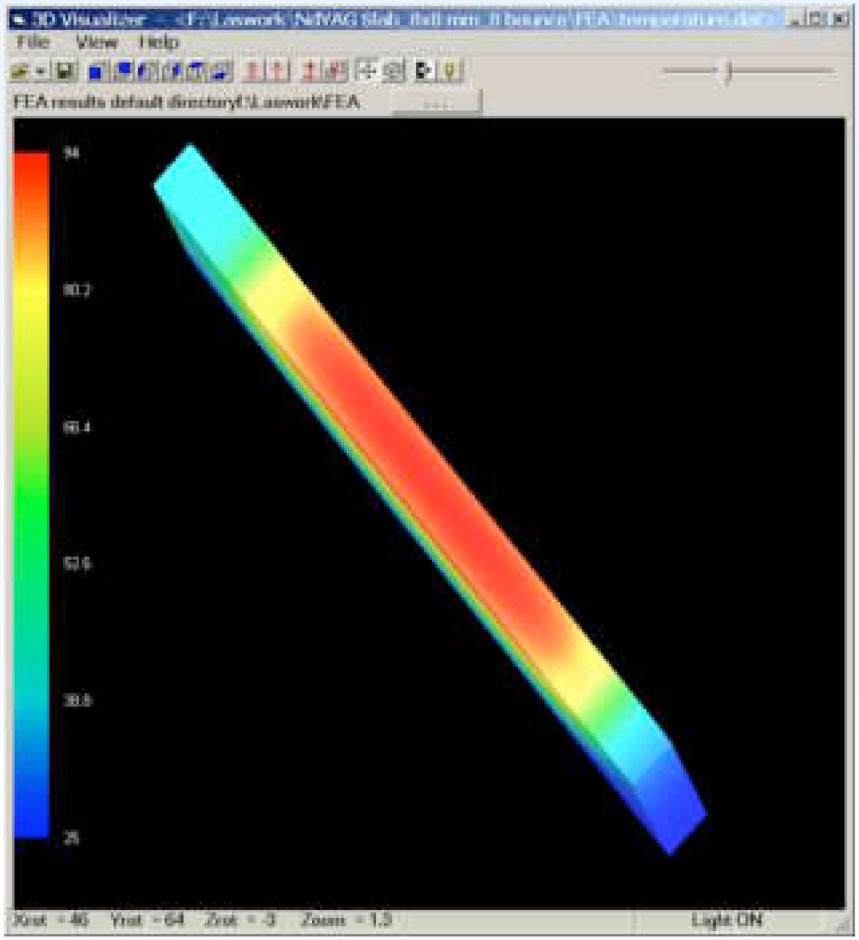
100 Hz, 20 mJ Oscillator

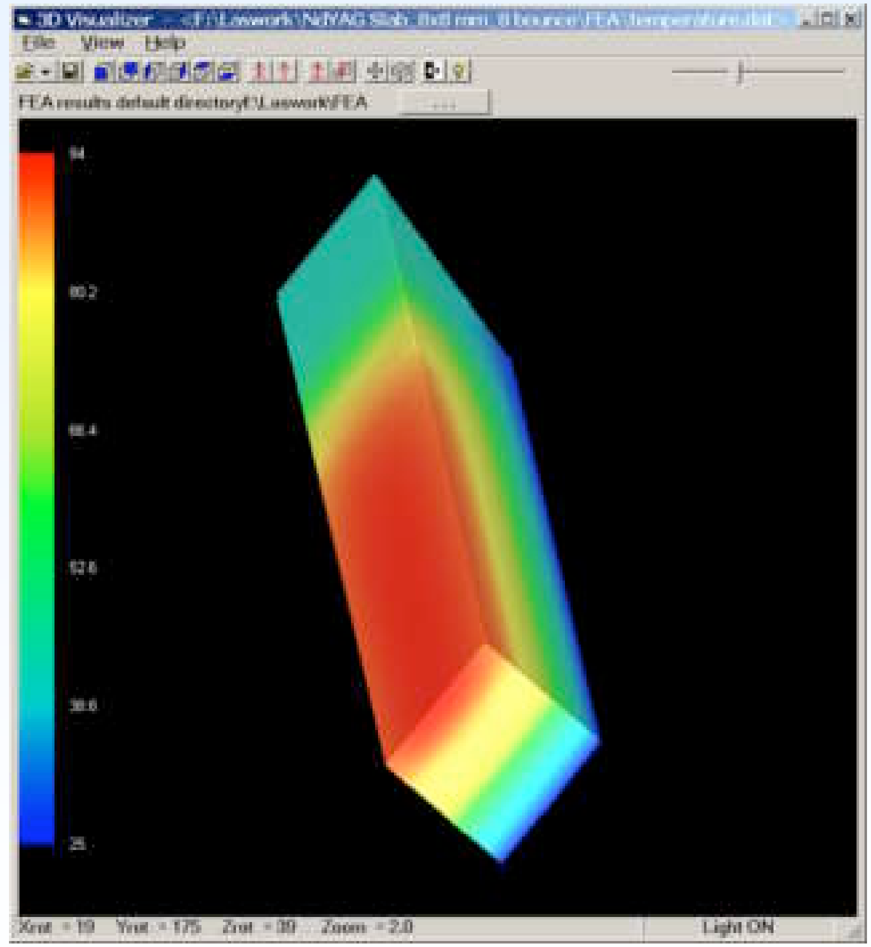


Amplifier Slabs

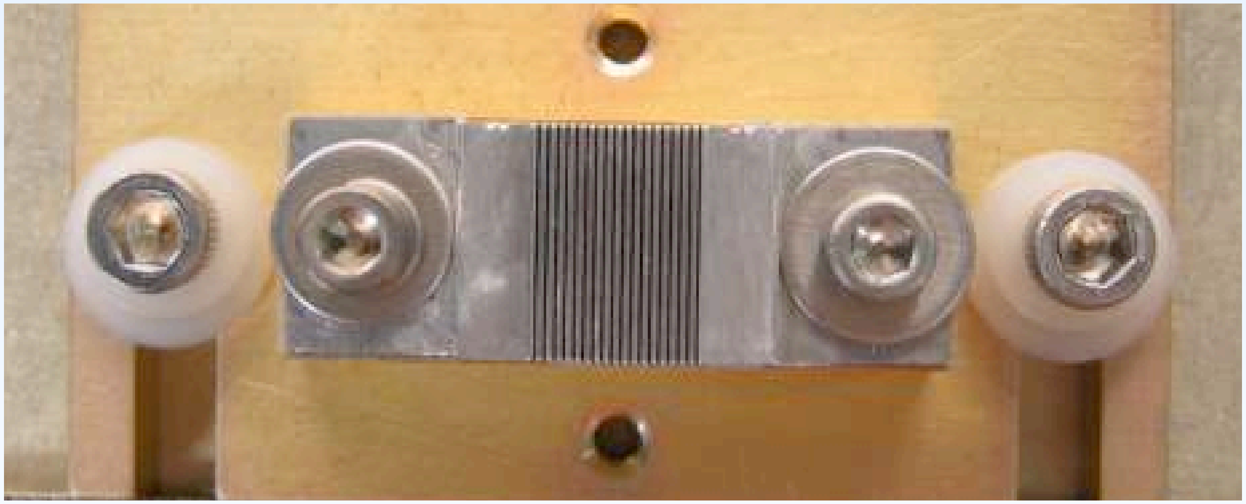


Amp Slab Thermal Analysis

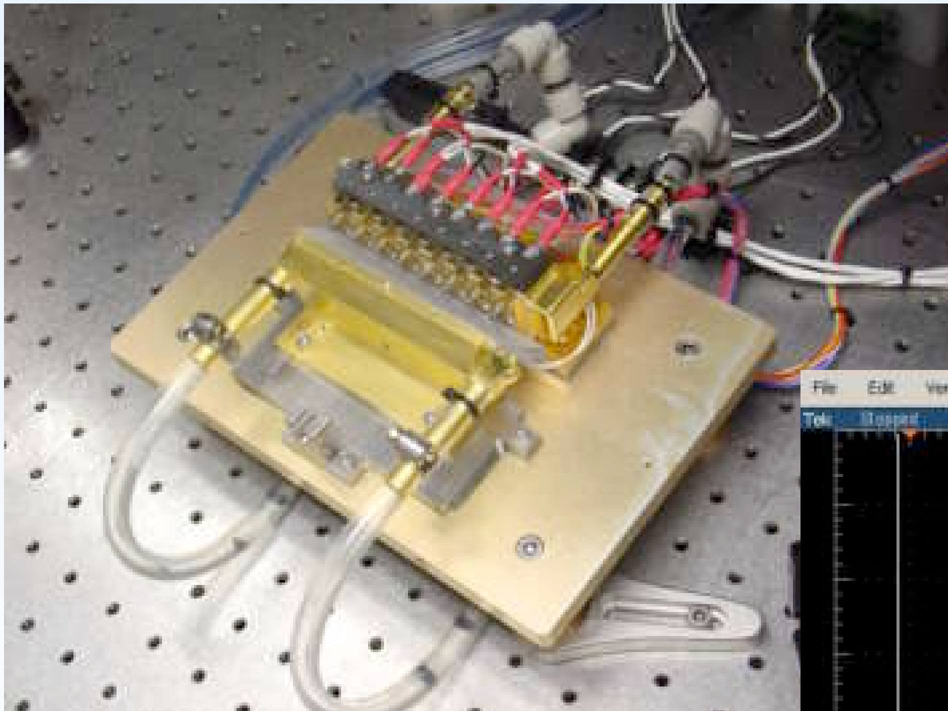


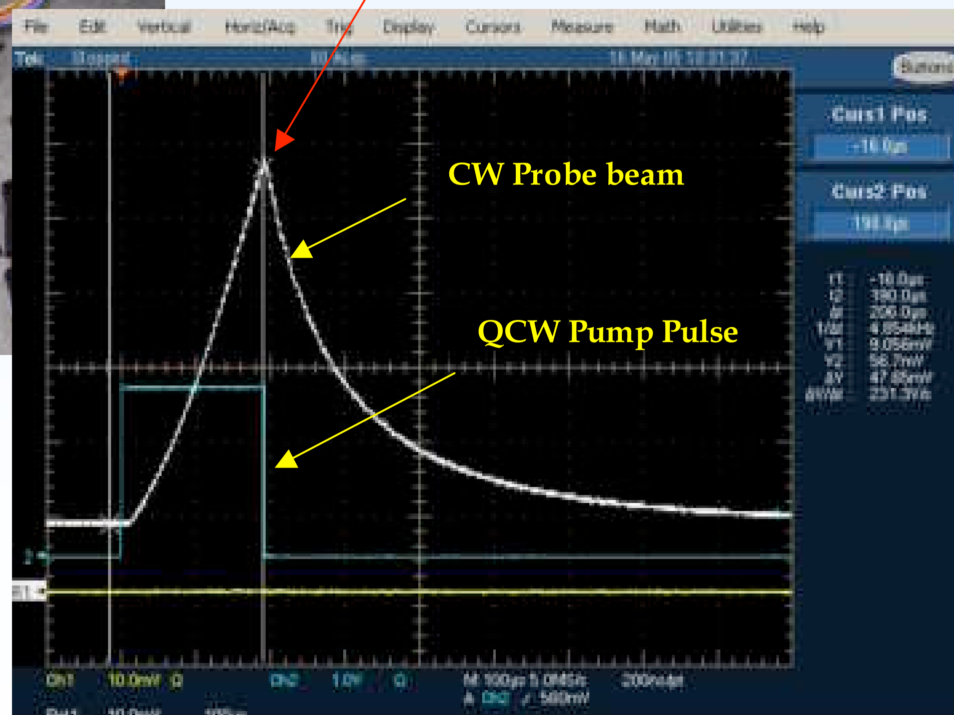


G18 Laser Diodes



Amplifier Small Signal Gain Measurement



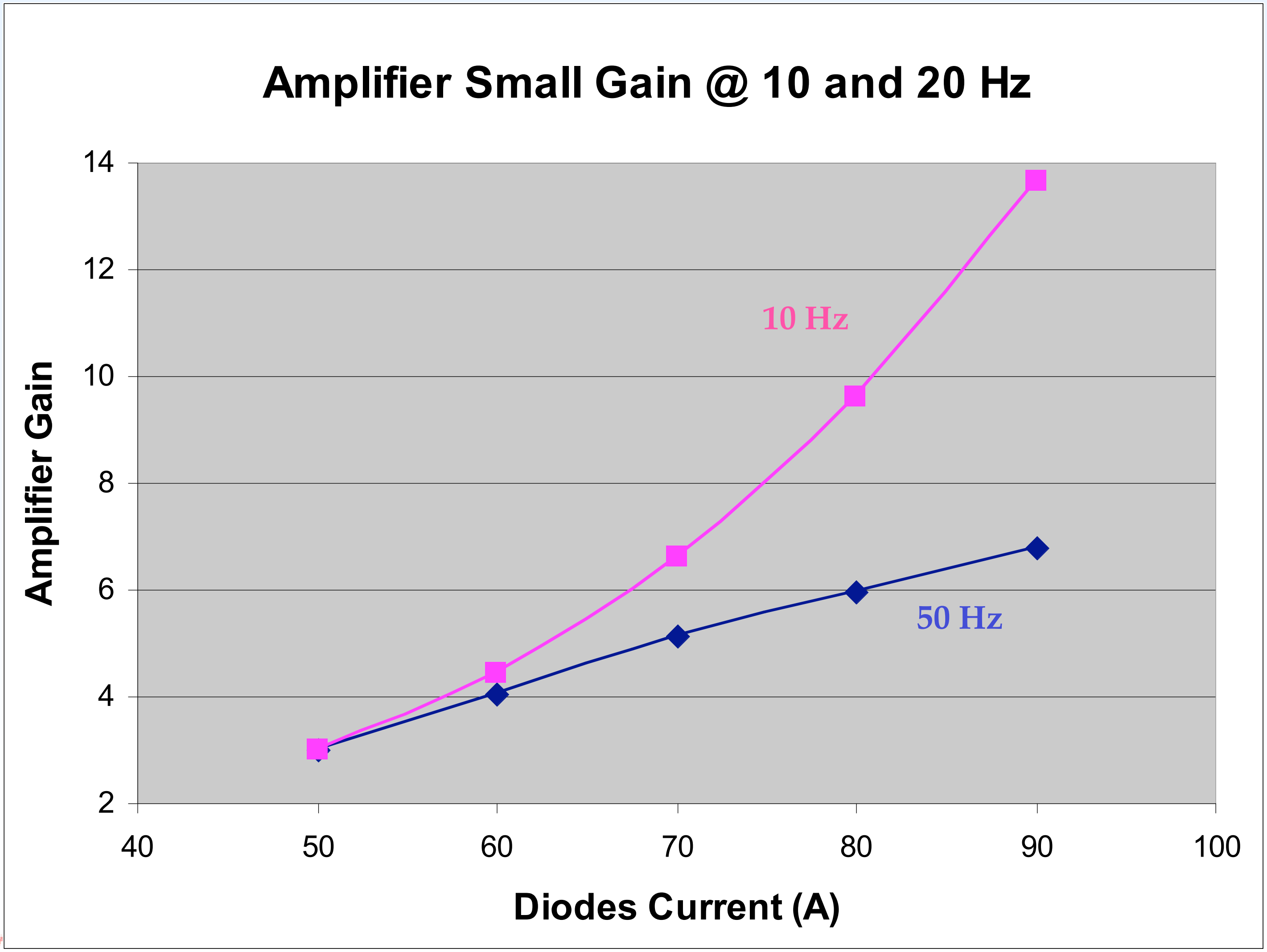


Small Signal Gain = 7

Pump Energy = 2 J/pulse @ 80A

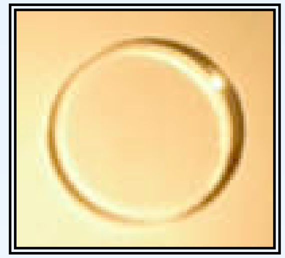
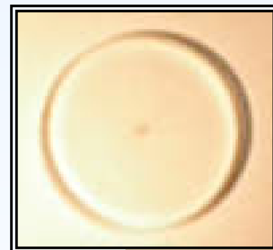
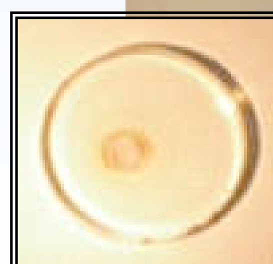
Repetition Rate = 50 Hz

Amplifier Gain Temperature Dependence



Environmental Effects

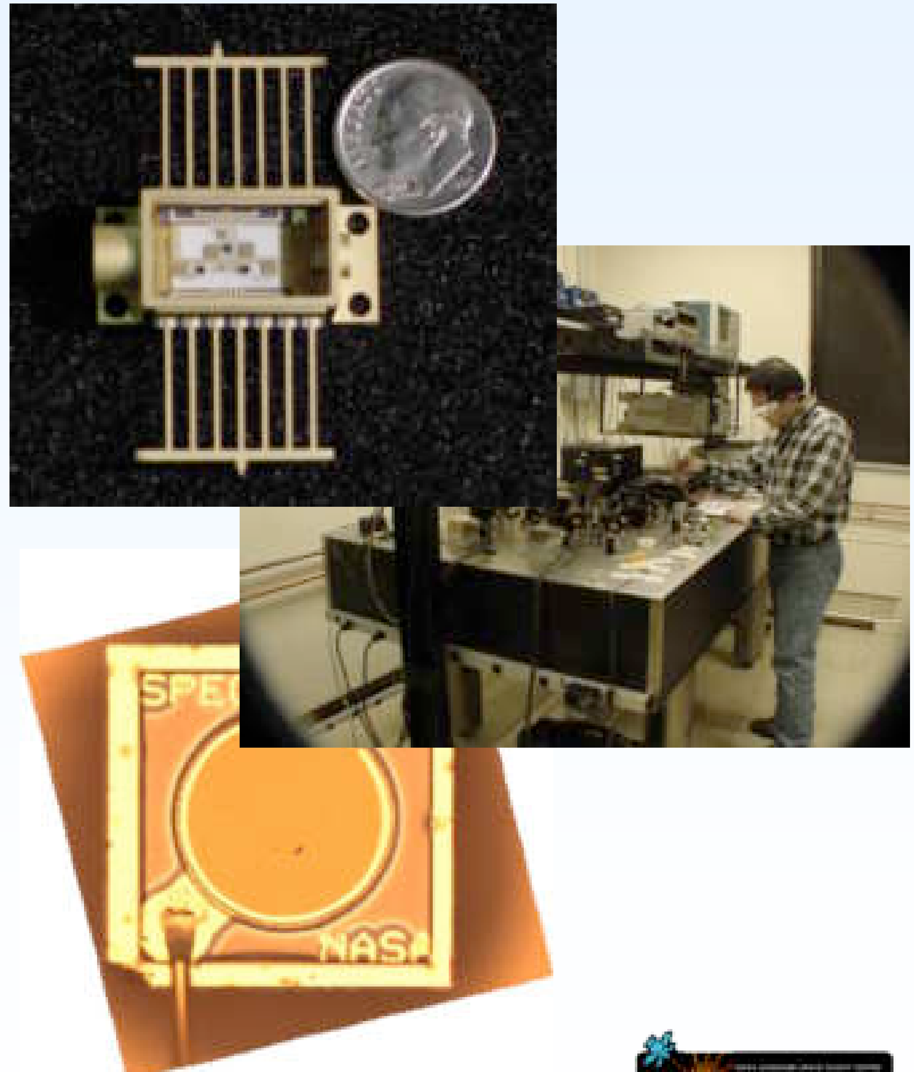
- Goals:
  - Understand laser induced optical damage as a function of materials, cleaning processes, operational environments, and laser wavelength.
  - Develop database of damage thresholds for commonly used adhesives and other flight materials.
  - Evaluate radiation tolerance of laser diodes and nonlinear optical components.

Detectors & Receivers

- Optical detectors with photon counting sensitivity over the 1.0 - 2.0 micron wavelength range:
- Quantum efficiency: 10 - 70%
- Detector size: 200 μm diameter
- Dark counts < 100 kcps
- Max count rate > 10 Mcps

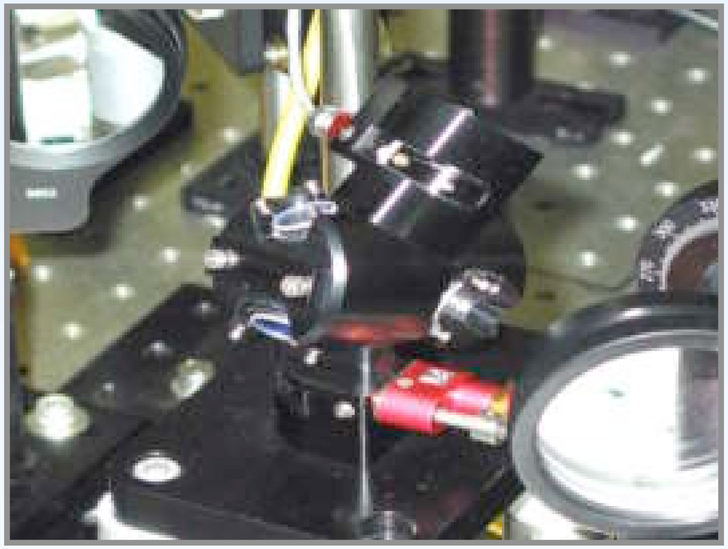
- Solid State APD: InGaAs photocathode, silicon or InAlAs avalanche region.

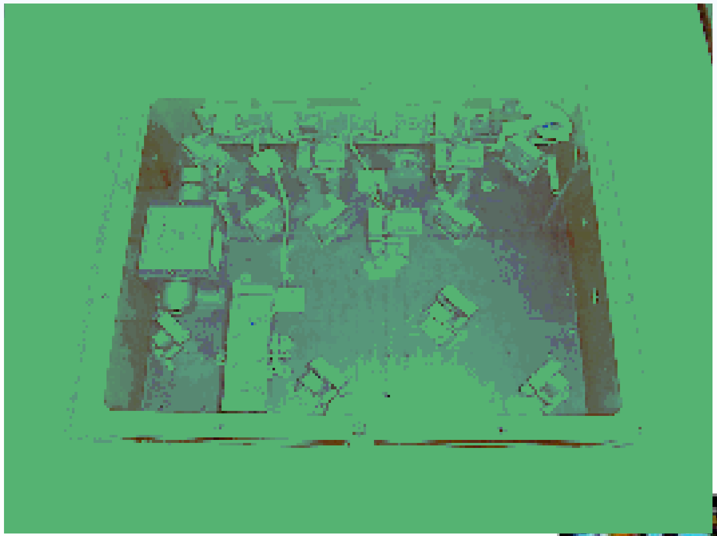


Frequency Conversion Technology & Materials

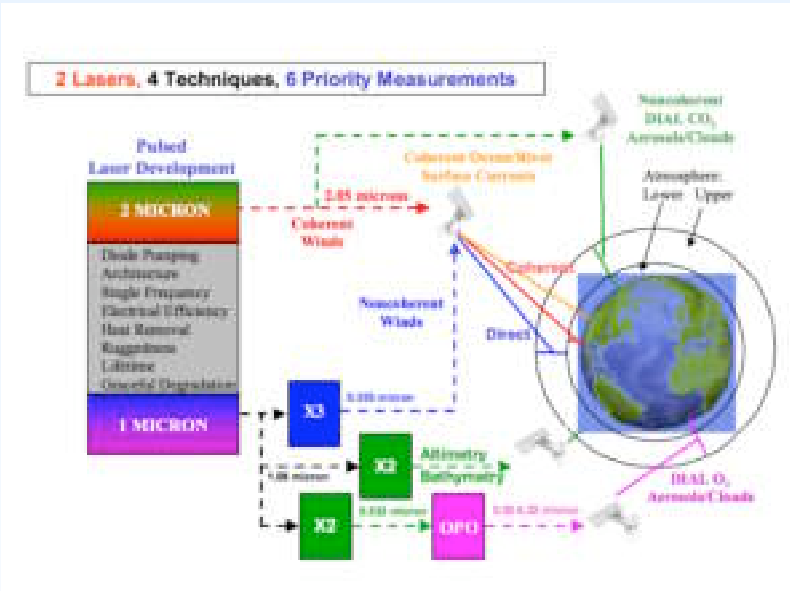
- Develop and demonstrate efficient non-linear optical technologies for the conversion of 1-micron pump laser light into alternate wavelengths required for various LIDAR measurements.
- Tunable IR range for profiling CO2
- Tunable, narrow band UV range for profiling ozone.
- Investigate the reliability and durability of nonlinear optical materials used in frequency conversion and in laser oscillator technologies.

- Develop efficient 1-micron to UV wavelength conversion technology to provide tunable, pulsed UV source capable of space-based operation in future NASA missions including Differential Absorption Lidar (DIAL) measurement of O3.





Risk Factors addressed by LRRP Tasks



	Diode Pumping	Architecture	Single Frequency	Electrical Efficiency	Heat Removal	Ruggedness	Lifetime	Graceful Degradation	Contamination Tolerance	Laser Induced Damage	Spectroscopic Frequencies	Detector Technology
1 micron Laser Architecture	♉	♉	♉	♉	♉	♉	♉	♉				
High Power Laser Diode Arrays	♉					♉	♉	♉				
Environmental Effects	♉					♉	♉	♉	♉	♉		
Freq. Conv. & Nonlinear Materials		♉				♉	♉	♉			♉	
Detectors				♉								♉
Knowledge Capture & Management	♉	♉				♉	♉	♉	♉	♉		

Conclusions

- Laser Risk Reduction Program is in its fourth year
- Effort supports Earth Science, Space Science as well as the new Exploration Program
- Variety of technologies to improve laser reliability
  - Thermal Management
  - Reliability of components (particularly pump diodes)
  - Contamination
  - Optical Mounts
  - Laser Architecture

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